

THURSDAY, SEPTEMBER 30, 1897.

HISTORY OF ATOMIC PHILOSOPHY.

Histoire de la Philosophie Atomistique. Par Léopold Mabileau, Professeur de Philosophie à la Faculté des Lettres de Caen. 8vo. Pp. vii + 560. (Paris: Félix Alcan, 1895.)

ALL things considered,¹ it seems probable that God, in the beginning, formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes, figures, and with such other properties, and in such proportion to space, as most conduced to the end for which He formed them; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break to pieces; no ordinary power being able to divide what God himself made one in the first creation.

"While the particles continue entire, they may compose bodies of one and the same nature and texture in all ages; but should they wear away, or break in pieces, the nature of things depending on them would be changed. Water and earth composed of old worn particles would not be of the same nature and texture now with water and earth composed of entire particles at the beginning. And therefore, that nature may be lasting, the changes of corporeal things are to be placed only in various separations, and new associations, and motions of these permanent particles; compound particles being apt to break, not in the midst of solid particles, but where these particles are laid together and touch in a few points."

This statement of Newton's unites in a singularly complete fashion the various aspects of the atomic theory of which M. Mabileau has given us a history in 560 large octavo pages. The author begins with a study of Kanada's theory, as examined by Colebrooke in his "Essays." Proceeding to the history of the subject in Greece, he leaves us in some doubt as to the precise influence of these earlier Hindu doctrines on the various Greek cosmogonies which, as he shows, developed in a natural and logical sequence in the hands of Thales, Anaximenes, Anaximander, Pythagoras, the Eleatic School, and Heraclitus, into a body of doctrines from which Leucippus and his disciple Democritus created the atomic theory, in a form but little different from that adopted centuries later by Newton. For Democritus, as for the modern chemist, composition was a union of atoms, and decomposition a separation of atoms, and matter, consisting ultimately of these atoms, was indestructible.

We have no space to follow M. Mabileau in his detailed account of the modifications of the doctrine of Democritus by Epicurus; of its criticism by Aristotle; its revival in poetic form by Lucretius; and of the monotheistic atomic theory of the Motécallemîn in the Middle Ages, so fiercely attacked by Maimonides in his "Guide for the Strayed." There are, indeed, two aspects of the atomic theory (sufficiently apparent in the quotation from Newton given above) which, though

perhaps not fundamentally separable, may yet be studied separately: the cosmical aspect, which offers us a hypothetical history of the universe; and the physical aspect, which offers us a hypothetical interpretation of actual phenomena. The study of the former aspect involves questions of religion and ethics, to which M. Mabileau very rightly devotes considerable attention; but we have neither the space nor the competence to follow him far on this ground. The interest of the atomic theory from the scientific point of view begins again, after Epicurus, with the alchemists, who are claimed by the author as more or less conscious atomists; a view which might be discussed. But the great return to the theory came, of course, with the Renaissance and the return to the reading of Greek philosophers in the original. M. Mabileau dismisses contemptuously the claims put forward by Lasswitz² for the Italians Giordano Bruno, Cardan, and Telesio as advocates of various forms of the theory, but, curiously enough, omits to mention Galileo, who can hardly be passed over in this connection.³

Bacon, already in the "Novum Organum" (1621) declared Democritus to have been the greatest philosopher of antiquity, but M. Mabileau agrees with both Lange⁴ and Lasswitz (and opposes Pilon and others), in regarding Gassendi's development of the doctrine of Democritus and Epicurus in the second quarter of the seventeenth century as the real turning point in its history,⁵ and he even thinks that Gassendi's claims have been somewhat underrated hitherto; but if this is so, it is rather as a precursor of what M. Mabileau calls Leibniz's "pan-psychical" monadology, than as a figure in the history of science.

Opposing Descartes' identification of matter with extension, Gassendi adopted the idea of solid, impenetrable and indivisible atoms, created in the beginning with certain properties as regards their movement in space, which control their future destinies completely; in addition he attributed to them a certain limited sensibility.

Gassendi is important from the scientific point of view, because he influenced Boyle,⁶ who speaks of him in terms of sincere admiration.

We must remember that Boyle was the author of the modern theory and definition of the elements (a fact which M. Mabileau, in his philosophic conviction that all matter is ultimately identical, passes over in silence); and that the conception of chemical combination, which has resulted from Dalton's theory, is thus really traceable to Boyle: though, as Roscoe and Harden have shown recently, it was, in its inception, due directly to the "Newtonian doctrine of repulsive atoms or particles."⁷

Very possibly, as M. Mabileau thinks, Newton took Gassendi's doctrine from Boyle. To Newton's own view M. Mabileau attributes the greatest importance, for he finds in him the mainstay of the atomic theory in its

¹ In his able and learned "Geschichte der Atomistik vom Mittelalter bis Newton."

² *Op. cit.* ii. 37 sqq.

³ In his "History of Materialism," translated by E. C. Thomas.

⁴ Lasswitz says: "Es war dieser Rückgriff auf die antike Atomistik, wenn er auch für die Geschichte der Philosophie keinen neuen Gedanken enthält, doch ein schöpferische That in der Geschichte der Physik."

⁵ See, in Boyle's works, "Considerations . . . touching the origin of forms," and especially vol. ii. p. 483 (folio edition).

⁶ Roscoe and Harden's "New View of the Atomic Theory," p. 14 (published after M. Mabileau's work).

⁷ "Newton's Opticks," 2nd edit. (1768), Query 31, p. 375.

widest sense. Unfortunately he totally misunderstands, if we are not mistaken, Newton's position.

It will be noticed that Newton puts his hypothesis among his famous *Queries*; he never abandoned the reserve expressed in his "Regulæ Philosophandi."¹

And secondly, when M. Mabilleau says that the theory of gravitation "means nothing if it does not mean that each atom of one body gravitates independently towards each atom of . . . (any other) body," because Newton said that the gravitation of a celestial body is the sum of the gravitations of all the *masses* of which it is composed, he appears to have been misled by the ordinary language of infinitesimal analysis. The atomic hypothesis essentially involves the discontinuity of all bodies. The theory of gravitation is equally true on the supposition that they are continuous, and, as a matter of fact, discontinuity of internal constitution is not taken into account in the mathematical analysis of gravitational phenomena. The point is of importance in judging M. Mabilleau's personal views, because, regarding Newton's law as "dans l'ordre des expressions phénoménales, la plus parfaite des formules, étant la généralisation et la plus haute et la plus exacte tout ensemble," he fallaciously adduces it as one of his most powerful arguments in favour of atomism.

M. Mabilleau discusses in some detail the views of Newton's contemporaries, Locke and Leibniz, those of Maupertuis, and later the dynamic theory of Boscovich. But from the time of Newton onwards he seems not only to have little acquaintance at first hand with his facts, but to be deserted by the powers of analysis and critical judgment shown earlier in the book. In his rapid rush through modern text-books and the popular articles of the *Revue Scientifique*,² he passes over the supremely important period of Black, Cavendish, Priestley and Lavoisier, in which the experimental method for comparing quantities of matter, failing which all theories of conservation of matter had been sterile, was arrived at; but quotes approvingly a view of "the great chemist Fechner" (who wrote two unimportant papers on chemistry) with regard to the connection between Newton and Dalton. He then analyses Dalton's work with some accuracy, and passes on to a *résumé* of the development of the atomic theory in chemistry since Dalton's time, mainly derived from Sir Henry Roscoe's address to the British Association in 1887, and Sir W. Crookes' lecture on the evolution of the elements. He notices the importance of modern theories of organic chemistry, but he fails altogether to recognise that (together with certain recent developments of chemical physics) they form absolutely the mainstay of the atomic theory in science. It is often hardly realised how unproductive of practical results the atomic theory has been

elsewhere. Incidentally M. Mabilleau makes many mistakes, which imply a curious failure in the power to grasp a new subject, indispensable to the historian. Victor Meyer is supposed to have decomposed the atoms of simple substances; Joule to have proved that any change in molecular constitution is accompanied by an absorption of heat, and thereby to have inaugurated thermo-chemistry in 1872 (!); &c. The function of the atomic theory in physics is discussed in the brief space of five pages, devoted chiefly to the transformation of crystal forms with increase of temperature, and after a scarcely sufficient account of modern criticisms of the idea of continuity in pure mathematics, M. Mabilleau's book concludes.

He sums up in favour of the existence of atoms controlled by a transcendental law given at the creation of the world, the last sentence of the book being "Voltaire nous avait bien dit que la philosophie corpusculaire est le plus court chemin pour trouver l'Âme et Dieu."

This sentence explains the whole book, which is rather like the special pleading of an extremely supple-minded barrister than the work of an impartial historian. M. Mabilleau's book was written as a prize essay, and it obtained a prize from the French Académie des Sciences morales et politiques. But it was evidently written in a limited time, and, in consequence, M. Mabilleau's references are (and he does not conceal the fact) mainly second-hand. With references of this kind only an expert can deal with any degree of safety, and in scientific matters, as we have seen, M. Mabilleau is far from being such.

For the historian of philosophy, M. Mabilleau's compilation will be useful. To the logical analysis of modern molecular and atomic theories, to which Stallo, Lasswitz, Mach, Pearson, Ostwald, and others have made valuable contributions, and which is still far from being exhausted, he adds nothing.

In conclusion, we may note that the book, though admirably printed and well arranged, has a most meagre table of contents and no index. P. J. HARTOG.

MAXWELL'S EQUATIONS OF THE ELECTRO-MAGNETIC FIELD.

Theory of Electricity and Magnetism. By Charles Emerson Curry, Ph.D. With a preface by Prof. Boltzmann. Pp. xv + 442. (London: Macmillan and Co., Ltd., 1897.)

A WORK on electricity and magnetism which, starting from the differential equations of the electro-magnetic field, works backwards to the experimental phenomena, cannot well be used as a text-book by the beginner, but may be of great value to one who has already studied the facts and theories of the subject in their historical order. Of such a nature is Dr. Curry's treatise, the avowed object of which is, after forming certain conceptions and making various assumptions concerning the ether which practically constitute a formulation of Maxwell's theory, to derive therefrom, and explain thereby, all electric and magnetic phenomena. It is, in fact, a study in the interpretation of differential equations in terms of mechanical analogies or concrete

¹ "In the particles [of bodies] that remain undivided, our minds are able to distinguish yet lesser parts, as is mathematically demonstrated. But whether the parts so distinguished and not yet divided, may, by the powers of nature, be actually divided and separated from one another, we cannot certainly determine." (*Principia*, trans. by Motte, edit. 1803, ii. 161.)

² In which he misspells the names of most of the people he quotes, whether they are French or not. Thus we find, almost throughout, Schutzenberger for Schutzenberger, Malard for Mallard, Würtz for Wurtz, Hoffmann for Hofmann, Thorsen for Thomsen, Jungfleisch for Jungfleisch, Kirchhoff for Kirchhoff, Lockyer for Lockyer, Krug (p. 521) for Krüss, Carnelly for Carnelley, Kékulé for Kekulé, &c. In one or two places Boyle is written Bayle, which might lead to confusion. But the climax is attained when, after some hesitation between the spellings Proust and Proust, with reference to the work done by these two chemists, the one English, the other French, M. Mabilleau identifies them boldly by writing (p. 516) "Proust (ou Proust)." Earlier in the volume we find Munk everywhere for Munk, &c.

representations, and is an interesting example of the manner in which the theory of electricity and magnetism is treated on the continent.

It is assumed that electric phenomena are due to motion of some sort going on in every volume element of the ether, and the displacement produced by this motion is represented by a vector called the "tonic vector." Quadratic functions of the time differentials of the components of this vector are then assumed for the kinetic energy and the rate of conversion of electrical energy into heat, while the potential of the forces which resist the tonic motion is assumed to be a quadratic function of the curls of the same vector. The application of Hamilton's principle at once gives the equations of motion of the ether, and these, by a slight modification, become identical with Maxwell's equations. This modification is described by the author as a change in the system of units, but it is really a change in the system of quantities discussed.

In nearly all works on electricity this subject of units is treated in such a way that it presents a serious stumbling-block to the student. He is, for instance, almost led by the phraseology to suppose that quantities of electricity in the electrostatic and electromagnetic systems are quantities of precisely the same nature, just as are a pound and a gramme of water, for example; but that, being regarded from different points of view, they have somehow different dimensions in terms of the fundamental units; and not infrequently, by an exercise of faith rather than of reason, he believes this. A quantity of water may be measured either by its mass or by its volume, and, loosely speaking, either result is the measure of the quantity of water. But, speaking accurately, we cannot measure the quantity of water; we can measure certain properties of that quantity, of which one is the mass and another and different property is the volume. In a precisely similar manner electricity measured by the electrostatic system is one property of the electricity, and electricity measured by the electromagnetic system is another property; either may be arbitrarily defined as the quantity of the electricity, but it is inconsistent and misleading to describe both properties by the same name.

The concrete representation suggested as an interpretation of the Maxwellian equations is modelled on the theory of von Helmholtz, and is characterised by three main features. The first of these is the familiar conception of two incompressible fluids, the positive and negative *real* electricities; in a dielectric the real electricity is supposed to be bound, so that it cannot move out of the volume element in which it exists; but in a conducting medium it is capable of moving, and does so with a velocity proportional to the force acting on it. It is then found that, in the electrostatic state, the force acting on the real electricity is such as would be due to a certain distribution throughout space of a substance which repels the real electricity according to the law of the inverse square. An arbitrary multiple of the density of this supposed substance is defined as the density of the *free* electricity, and this constitutes the second main feature of the concrete representation. To bring about some simple relation between these two sorts of electricity the third main feature is

introduced, namely the conception of electric polarisation; it is supposed that the real electricity within any volume element is capable of moving in such a way under the influence of electromotive force that positive electricity appears at one end of the element and negative at the other; thus there arises a density of electricity due to electric polarisation, and the definitions are such that at any point the density of the free electricity proves to be equal to the sum of the densities of the real electricity and of that due to polarisation.

Round these three conceptions are gathered several subsidiary definitions and suppositions, the mathematical reasoning being intricate and detailed; the whole constitutes a scheme of considerable complexity, of which indeed it is difficult to form a clear conception; as a physical theory, it would of course be extremely unnatural, but as a mere illustrative analogy it is instructive.

After considering Maxwell's equations of action at a distance, Dr. Curry shows by what assumptions and what modifications of the concrete representation we may pass from them to von Helmholtz's scheme; and he then considers the independent derivation of the latter from empirical laws.

There is an interesting chapter on the theory of the Hertzian oscillations, founded on Hertz's own memoir, but with the analysis given in greater detail. Other chapters deal with cyclic motions and illustrative mechanisms, with longitudinal ether oscillations, and with the theory of electric and magnetic striction.

The work is, on the whole, characterised by a clear style, though several serious difficulties are ignored, and some of the main features in the reasoning are not emphasised as their importance deserves. Thus in the transition from Maxwell's to von Helmholtz's equations the reader is left in considerable doubt as to whether certain of the suggested modifications are purely arbitrary assumptions corresponding to radical changes in the concrete representation, or merely a presenting of the old differential equations in a slightly altered form. There are also some serious errors which greatly disfigure the book, though fortunately they do not invalidate the leading argument. Thus on page 33 we are offered two different schemes of the dimensions of the quantities of the electrostatic system in terms of the fundamental units, a result due to a confusion of angular momentum with density of angular momentum. The kinematics on page 10 are faulty; and on page 23 we find the dissipation function spoken of as an energy function, and actually treated as such in the application of Hamilton's principle.

J. G. L.

OUR BOOK SHELF.

Reform of Chemical and Physical Calculations. By C. J. T. Hanssen, C.E. Pp. xvi + 72. (London: E. and F. N. Spon, Ltd., 1897.)

THE book deals specially with calculations of specific and latent heat, and heat of combustion of various substances. In the preface the author states that all his deductions are based upon the natural laws of atomic combination, heating, expansion and compression of aeriform substances, upon a few of the best substantiated experiments, and upon the fact, discovered by the author, that, near the 41° of latitude, the specific gravity of

oxygen gas of atmospheric density, at the temperature of freezing water, is exactly $1/700$ of the gravity of distilled water, at its temperature of greatest density. He advocates this as an international circle of latitude for all gravitational calculations. The author says that "from this fact as a starting point, all fundamental values have been determined, and expressed with absolute exactness in units and vulgar fractions instead of approximately by rows of decimals," and he claims that his arithmetical method gives an "absolute accuracy of results, and a facility of manipulation not attainable by any other known method."

It is possible that the use of convenient vulgar fractions for physical constants may conduce to facility of arithmetical manipulation, but the author, for the sake of his vulgar fractions, makes assumptions which can surely not conduce to the absolute accuracy which he claims. For example, he takes $17/12$ as the ratio between the specific heats of gases at constant pressure and at constant volume, because $17/12$ is a simple fraction not far removed from the determined value of the ratio for simple gases, and, moreover, in spite of experimental evidence to the contrary he uses the same ratio in the case of such gases as CO_2 . The author also advocates, and uses, a new scale of temperatures, not very different from the absolute Centigrade scale, to facilitate his arithmetical work. This he calls the normal scale.

The author makes a great number of calculations, arranging the results in tables. Where experimental evidence is at variance with any of these results he considers the experiments are inaccurate. The arithmetical work is conducted with considerable ingenuity, though occasionally the mode of statement of details is not unexceptionable, e.g. (on p. 24), $\log 0'00000 - \log 0'21249 = \log 1'78751 = 0'61307$.

Prof. G. Karsten, of Kiel, has written an introduction to the book, in which he calls special attention to the author's proposal (mentioned above) that all observations and calculations on gravity should be referred to one common international circle of latitude, to be called the circle of international gravity. He also mentions § 80 and Table xxii. as samples of the satisfactory results of the author's calculations and observations on heat produced by combustion, and recommends the book to the attention of scientific men.

The book on the whole, though the calculations are, in many parts, of considerable and varied interest, does not seem to justify its ambitious title.

Citizen Bird: Scenes from Bird-life in plain English for Beginners. By Mabel Osgood Wright and Elliot Coues. Pp. xiv + 430. (New York: The Macmillan Company. London: Macmillan and Co., Ltd., 1897.)

THIS book consists of a series of pleasant dialogues between Dr. Roy Hunter and some children, at Orchard Farm in New England, in which the children learn the appearance and habits of a great number of the birds around them. It has been rather unfairly compared in a daily paper to "Sandford and Merton." It must be allowed that the didactic dialogue is apt to be tiresome, and in this case the children are of course a little unnatural in their acuteness and their ardent desire to learn. English boys would probably learn better from a sound and scholarly handbook: one in whose hands I to-day placed Sir Humphry Davy's "Salmonia," after a few days' trout-fishing, not unjustly complained that Halieutes and his pupils always caught exactly the fish they wanted—which was not the case when he was fishing. It may perhaps be doubted whether the experiment would answer on this side the water.

But the familiar names of Dr. Coues and Miss M. A. Wright are a more than sufficient guarantee of the excellence of the ornithological part of the book, and to

English students of bird-life it will be of real value. Here we have the actual every-day life of the birds most familiar to the New Englander, which very few of us can hope ever to study in their own homes. Many of them, of course, closely resemble our own, and a very few are identical with ours. But the great majority are new to us, and of these we learn very pleasantly from this book something that we could not have picked up except by crossing the Atlantic ourselves. The photographic illustrations are excellent; and there is a useful index and a classification of North American birds. But perhaps the best thing in the book is the account given by Mammy Bun, the negress, of the mocking-bird as she knew it in the Southern States.

W. WARDE FOWLER.

LETTER TO THE EDITOR.

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The Worstest Test for Colour Vision.

IN NATURE of September 23 reference is made to the death of Dr. A. F. Holmgren, professor of physiology in Upsala University. "His attention," it is said, "was in the early seventies directed to colour-blindness, and in 1878, he published his well-known work on colour-blindness in relation to railways and the Navy, thus bringing to a practical issue the work long before begun by George Wilson, of Edinburgh (1855). This led him to the invention of his now well-known worstest test for colour vision."

May I be allowed to say that Prof. George Wilson, of Edinburgh (my brother) was, during a long series of investigations as to the nature and extent of this peculiarity of vision, constantly in the habit of using the "worsted test." In his work, "Researches on Colour Blindness" (published in 1855 by Messrs. Sutherland and Knox, Edinburgh, and Simpkin, Marshall, and Co., London), references very frequently occur to the use of wools as a colour test. On page 25 he says, "Dr. Y., aged 27, when requested to match coloured worsteds by daylight placed the full reds and greens together, but when the same skeins were placed before him by gaslight, he picked out the greens and placed them apart."

At page 44, while examining artillery soldiers at Leith Fort, he put into the hands of one man a bundle of coloured wools, from which he was to make a selection. The soldier was nervous, but retained with firm grasp a yellow skein of wool, putting it in the bundle containing red purple and red brown, with manifest perplexity at all the colours being alike. Page 40, soldiers in the Edinburgh garrison, known by previous experiments to be colour-blind, were closely watched while from a heap of coloured wools each one was asked to select first the red skeins and then the green, no notice being taken of the selection made till eight or nine skeins were set aside as red and the same number as green.

At page 70, 437 soldiers were asked to assort coloured papers, wools, and pieces of glass, and to place those of the same hue together. At page 77 a young Kaffir gentleman, whose knowledge of English was limited, was asked to match Berlin wools and tinted papers.

One advantage gained by making wools the test, was that many of the colour-blind have a specially keen sense of minute details, so that in seeing the same object more than once, they would recognise it by some small point or wrinkle or crease, scarcely perceptible to an ordinary observer. In the wool test this power was of no service to them.

I think from the examples quoted (and many more might be given), priority in making use of the "worsted test" may fairly be claimed for Prof. George Wilson. At many of the lectures given by him on this subject a diagram was exhibited, consisting of a square of calico to which were attached specimens of wools as selected by the colour-blind tested by him. In the course of time the colours faded, so as to lessen its value, and it was put aside.

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THE SOCIAL SYSTEM OF TERMITES.¹

THOUGH more than a century has elapsed since Smeathman published the first careful account of Termitidae, but few workers have substantially increased our knowledge of the subject. The reasons for this apparent apathy lie, indeed, on the surface. With few exceptions the Termites are tropical or sub-tropical in habitat; avoiding light, and living in vast concealed communities, their cryptic manner of life renders the task of observation extremely prolonged and arduous, while the multiplicity of forms in a single species, and the difficulties attending their preservation, have earned them little regard from the systematist.

The first marked advance towards unravelling the complexity of the Termite community was made by the great naturalist so lately lost to science, Fritz Müller. Following out Lespès' observations on the nymphs, he showed that a certain number of Termitidae reach maturity and propagate without leaving the nest or acquiring the imaginal characteristics, and contended that the function of the swarming adults was not that of founding fresh colonies, but of furnishing royal pairs to pre-existing orphaned nests.

His conclusions were supported by observations in nature, but were not made the subject of experiment; they are to be regarded as suggestions, which, however, approach very nearly to the truth.

The subject was taken up by Prof. Grassi in order to investigate the origin of the sterile castes, and the results of seven years' labour have been put forward in a monograph which, for the first time, places the nature of the Termite society beyond the reach of speculation. Intricate as the memoir is in the presentation of facts and inferences, it cannot but leave the reader with a profound sense of the perseverance, fertility in experiment, and deductive ability which it reveals.

Species of two genera, *Calotermes* and *Termes*, were studied, and success was largely due to the fact that it was found possible to keep small numbers of the former genus alive for long periods in corked test-tubes containing rotten wood. Careful observation thus became practicable, and by varying the number and kind of individuals introduced, their development and inter-relations could be studied.

Grassi's work on *Calotermes* shows that the eggs are of one kind and the newly-hatched larvæ undifferentiated, the caste distinctions arising after birth, and depending on the development of the genitalia. If this proceeds normally, the larva ultimately becomes a winged imago; if it is arrested at any period before the completion of the nymph-stage, the larva becomes a soldier; and finally, if it is precociously stimulated, a neotenic form is produced, one, that is, which reaches sexual maturity without ever acquiring the imaginal characters. The insect remains plastic until the atrophic change of the genitalia has been set up; thus, a soldier-larva or soldier cannot be modified, but a nymph can be converted into a soldier possessing wing-buds (a "nymph-soldier"). These buds may be subsequently reabsorbed, so that a retrogression actually takes place. The colony is headed normally by a single king and queen derived from the perfect insects; should either or both be missing, their place is supplied by neotenic "substitute" forms, which are then always produced if the society contains examples capable of undergoing this modification. An orphaned colony may be made to produce a much larger number of substitutes if subdivided into small societies than if kept together, and the same is true of the soldiers. This and similar observations go clearly to show that the modification of these individuals is no way predestined.

The insects must possess the faculty for estimating a numerical ratio, and if the number of soldiers or royal substitutes is in excess of their needs, the supernumeraries are killed and eaten!

The colony of *Termes* is more complex and more difficult to study: it is similar in character except that it contains two sterile castes, soldiers and workers, and two kinds of neotenic forms; one, the "complementary royal forms" are constantly present in large numbers as the ordinary reproductive members; the other, the "substitute forms," are developed on an emergency to supply their loss. In Sicily, according to Grassi, the winged imagos are entirely lost after swarming, and never give rise to fresh societies; but there is evidence that this remarkable example of natural wastefulness is not constantly exhibited in France. According to Marlatt, the closely-allied *Termes flavipes* of North America is known to reproduce by means of complementary forms alone.

Grassi holds that the caste-modifications are caused by variation in nutriment, and records a series of minute observations on the rather repulsive feeding-habits of these insects, made chiefly by his coadjutor Dr. Sandias. The staple food is wood, passed and repassed through the alimentary canal of several individuals; the society tolerates no waste, and everything of nutritive value, cast skins and dead bodies alike, is greedily devoured.

Newly-born larvæ and forms destined for sexual maturity are fed upon the saliva of their comrades, the largest amount being given to those which are becoming neotenic; within forty-eight hours after its administration they become altered, acquiring ocular pigmentation and a translucent white appearance.

It is therefore contended that sexual development is directly stimulated by the saliva taken as food; but a disturbing factor has had to be eliminated. The alimentary canal of most Termites teems with protozoa, which bring about the dilatation of a caecal ampulla so as to fill the greater part of the abdomen. These protozoa disappear under the influence of a salivary diet, and the question has arisen whether the resulting diminution in size of the ampulla may cause the gonads to ripen. Grassi answers this in the negative. All Termites lose their parasitic protozoa at the time of moulting, and by taking advantage of this circumstance he has been able to keep colonies alive for a month or more entirely free from protozoa. A few examples only in these colonies became neotenic; and it is therefore clear that the saliva is one, if not the only, necessary factor in bringing about sexual maturity.

No light has been thrown on the causes which, in *Termes*, lead to the differentiation of the soldier from the worker; but it may be reasonably inferred that they are also due to differences in nutrition.

As already indicated, the results of this research are directly opposed to the hypothesis that special ova or special sets of "determinants" exist for the various castes in Termitidae. It is not necessary here to dwell upon this point, which, it may be recollected, has been dealt with conclusively by Mr. Herbert Spencer in his controversy with Prof. Weismann (*Contemporary Review*, October 1894).

The means by which the special characters of the sterile castes are inherited is a matter which has caused Prof. Grassi some trouble. In the original memoir he appears scarcely to have made up his mind on the point; but in a footnote appended to the English translation he puts forward the supposition previously advanced by him in the case of bees, that it is to be interpreted by the exceptional occurrence of soldiers and workers capable of oviposition. This view is supported by the discovery of a "nymph-soldier" with well-developed ovarian tubes. Much more evidence is still required as to the occasional existence of fertile soldiers and workers, especially in

¹ "The Constitution and Development of the Society of Termites, &c." By Prof. B. Grassi and Dr. A. Sandias. English translation in the *Quarterly Journal of Microscopical Science*, vols. 39 and 40; with five plates.

species, if such exist, in which the caste distinctions are still incipient. If it can be shown that the evolution of caste characters is in any way anterior to the loss of fertility, the difficulties of interpretation will disappear; at present the evidence points to the fact that owing to qualitative changes in nutrition, rather than simple malnutrition, an atrophy of the sexual organs is set up which is correlated with a hypertrophic modification of other structures, by a deflection, so to speak, of the nutritive stimulus.

Many neotenic forms show no trace of wings. If the termite colony were headed by such forms only, the phenomenon, as Grassi points out, would occasion no surprise, but all valid evidence would be wanting that the species had ever possessed wings. This leads to the admission on his part that there is no proof that all existing wingless insects may not be descended from winged ancestors, and in the absence of such a proof he is led to reject Brauer's division of Insecta into Apterygogenea and Pterygogenea.

Space forbids any reference to the full account of the social life, habits and instincts of the species which Prof. Grassi has studied. Their intelligence, though remarkable, is far inferior to that of ants, and may be profitably contrasted therewith. Whilst referring to this subject, it may be worth while to call the attention of those interested in animal psychology to two lately-published pamphlets on the subject, particularly that on the psychology of ants,¹ by Father Wasmann, a most careful observer and thorough student of animal intelligence.

One practical result of Grassi's work requires mention. An isolated group of ten or a dozen Termites, containing any forms which have not begun to undergo the atrophic changes induced in the sterile castes, is capable of converting such forms into reproductive individuals; and the little society, thus started, possesses the power of multiplying into a large colony.

It is therefore hopeless to attempt the extermination of Termites merely by the destruction of the kings and queens.

W. F. H. BLANDFORD.

PERIODICAL COMETS.

THE number of comets of short period which are expected to return to perihelion during the next two years is remarkable. In 1898 the following comets are due:—Pons-Winnecke (April), Encke (May), Swift, 1889 VI. (June), Wolf (June), Tempel, 1867 II. (September); in 1899, Denning, 1881 V. (January), Tempel, 1866 I. (March), Barnard, 1892 V. (April), Tuttle, 1858, I. (May), Holmes (May), and Tempel 1873 II. (July). In addition to these, 1898 may possibly witness a return of Biela's comet, last seen in 1852, and of Coggia's, 1873 VI.; but these are doubtful, and the prospect of re-observing them appears to be very limited. Thus there are thirteen known comets which may present themselves for detection, but several of them will be enabled to elude observation in consequence of their unfavourable position, and in one or two cases the objects may escape owing to the uncertainty now existing as to the exact periodic times.

Apart from the large number of interesting comets which are likely to be visible, several fine meteoric showers will probably occur, for the Leonids are due in considerable abundance on November 14, 1898, 1899 and 1900, while the Andromedes ought to reappear on November 23, 1898. Both for the cometary and meteoric observer we are, therefore, entering upon a period very prolific in important phenomena.

During the first quarter of the present century the number of cometary discoveries averaged about one per

annum. The present average is about five, including periodical comets, which represent no small proportion of the whole. The rapid increase, during the last twenty years, in the number of comets of short period is very striking, and proves not only that these bodies are exceedingly plentiful, but also that the field of discovery is not nearly exhausted. They belong to the Jovian family, with periods ranging from five to nine years. Encke's comet furnishes rather an exceptional case, the period being only 3·3 years, and considerably shorter than that of any other known.

Perhaps it may be interesting to make a brief seriatim reference to the expected comets of the next two years:—

Pons-Winnecke.—This comet, due in April 1898, was well observed at its last return to perihelion in June 1892. The ensuing return will not be so favourable, as the comet will be much more distant from the earth, and visible only in the morning sky. This return will be much the same as in 1875, four periods of the comet being equal to twenty-three years; thus perihelion occurred on June 30, both in 1869 and 1892.

Encke.—Returns in May 1898. The comet will not be so well placed, owing to its southern position, as at its last return, when it was quite conspicuous in December 1894 and January 1895. Observations may be made satisfactorily from the southern hemisphere after the perihelion passage, as in 1832 and 1865, when the comet was discovered in June. At intervals of thirty-three years (= 10 revolutions of the comet) it comes to perihelion at nearly same times as before, and its apparent path in the heavens is repeated.

Swift, 1889 VI.—Considerable uncertainty is attached to the orbit of this comet. Hind deduced a period of 8·534 years, which would bring the comet back at midsummer 1898; but Coniel has more recently determined the period as 8·92 years, with an uncertainty of 0·9 year. If this object is redetected, it will probably be picked up accidentally by some one engaged in comet-seeking. The most favourable returns are those when it reaches perihelion in October or November.

Wolf.—This comet, which will reach its perihelion in June 1898, was favourably observed in 1884 and 1891; but in 1898 the conditions are not nearly so good. The following ephemeris for the next return is by A. Berberick (*Ast. Journal*, 253).

Date.			R.A.		Dec.		Light.	
			h.	m.				
1898.—	June	3	...	1 42·3	...	+18 18	...	1·7
	July	5	...	3 18·3	...	+19 43	...	2·1
	Aug.	6	...	4 49·3	...	+16 51	...	2·3
	Sept.	7	...	6 4·9	...	+10 2	...	2·4
	Oct.	9	...	6 56·9	...	+0 38	...	2·4
	Nov.	10	...	7 17·9	...	−9 21	...	2·4
	Dec.	12	...	7 4·1	...	−16 20	...	2·1
1899.—	Jan.	13	...	6 34·1	...	−16 31	...	1·4

(Brightness May 1, 1891 = 1.)

(Brightness May 1, 1891 = 1.)

Dr. Berberick remarks that later returns of the comet will be unfavourable. Seven of its revolutions are equal to three of Jupiter, and a second approach of these bodies will occur in 1922–23, depriving us perhaps of the sight of the comet for a long time, if not for ever.

Tempel, 1867 II.—Comes to perihelion in September 1898. This comet was re-observed in 1873 and 1879, but has not been seen since, though it has twice returned to perihelion in the meantime. The conditions in 1898 are not very good. The periodic time was about six years in 1867, 1873 and 1879; but perturbations by Jupiter have considerably lengthened the period according to Gautier. It is most important that the comet should be redetected if possible.

Denning, 1881 V.—Returns to perihelion in January 1899, but under circumstances not nearly so favourable as in 1881. In January and February its distance from the earth will be about 100 millions of miles, and about

¹ "Instinct und Intelligenz im Thierreich," and "Vergleichende Studien über das Seelenleben der Ameisen und der höheren Thiere," by Erich Wasmann, S.J. (Freiburg, 1897).

the same as when last seen in the Strassburg refractor of 20 inches aperture, on November 24, 1881. In view of the doubts prevailing as to its exact period, it is questionable whether it will be redetected in 1899. At its following return in 1907 the comet ought to be conspicuously visible for some months, as it will be comparatively near to the earth, and the favourable return of 1881 will be repeated, three periodic revolutions ($1 = 8.687$ years) of the comet being equal to twenty-six years. At its last return in 1890 May, the position of the comet was such that it never approached within 150 millions of miles of the earth, and thus it entirely escaped observation.

Tempel, 1866 I.—This comet is due in the spring, but it will be separated from the earth by a much wider interval than in 1866. Its favourable returns are those when perihelion occurs in about November or December. If the comet has the same periodic time as its associated meteor shower (the Leonids), then it is well visible at one return only out of every three, and its next favourable apparition will occur in 1965-6.

Barnard, 1892 II.—The period of this faint comet (discovered by photography) is somewhat doubtful. Hind gave 6.64 years, Krueger 6.309, Porter 6.18, and Coniel 6.52. The comet will probably return to perihelion in the spring of 1899, when it will, however, be invisible, being obliterated in the sun's rays. When the comet reaches its perihelion in the autumn it can be well observed.

Holmes.—This comet returns to perihelion in April 1899 according to Zwiers, the probable error being 0.72 day. His orbit was derived from 600 observations. Dr. Kohlschütter has also given a definitive orbit for this comet, his periodic time for it being 2520.829 days, while Zwiers gives 2521.2 days. The latter, after allowing for perturbations by Jupiter and Saturn, gives April 27.97 as the date of perihelion, and his ephemeris for 1898, as abridged, is as follows:—

Greenwich Noon, 1898.			
	R.A. h. m.		Dec.
Feb. 16 ...	16 26	...	-42 7
Mar. 18 ...	16 52	...	-45 44
April 17 ...	17 0	...	-49 20
May 17 ...	16 41	...	-51 49
June 16 ...	16 5	...	-51 1
July 16 ...	15 46	...	-47 10
Aug. 15 ...	15 56	...	-43 2
Sept. 14 ...	16 31	...	-39 55

The comet must therefore be looked for at southern observatories, in 1898; it will be well placed for northern observers in 1899.

Tuttle.—This comet, first discovered by Mechain in 1790, and re-observed by Tuttle in 1858, was also seen in 1871 and 1885. It belongs to Saturn's comet family, its orbit, at aphelion, being just outside that of Saturn. The conditions are not favourable for seeing the comet at the ensuing return in the summer of 1899, as its longitude of perihelion is 116° , and perihelion distance 1.03, or about 3 millions of miles outside the earth's orbit. The comet is therefore best visible when it comes to perihelion at the end of January, the earth and comet being then on the same side of the sun, and only a few millions of miles distant from each other.

Tempel, 1873 I.—Returns early in July 1899, and will be observed under pretty good conditions, the earth and comet being on the same side of the sun. The comet will be visible during the whole night, and is likely to be as successfully observed as in 1873, when it was first discovered, for five of its periods of 5.20 years are equal to twenty-six years.

No doubt some of our largest telescopes will be employed in the redetection of these objects as they severally return to perihelion. In recent years the diligence of observers has been the means of increasing the number of periodical comets at the average rate of one per year,

and this increase will probably be maintained, if not exceeded, in the future.

It might be supposed that comets returning to the sun at comparatively short intervals would soon be all detected; but when the circumstances are considered, it will be seen that this state of things will be never realised. The comets of short period are faint objects, and often pass their perihelia under conditions which render them totally invisible. Thus De Vico's of 1844 was computed by Brünnow to have a period of 5.469 years, but it was not seen again until 1894, though during the fifty years it had returned unobserved on eight occasions. Pons's comet of 1819 was assigned a period of 5.618 years by Encke, but it was not seen at any of the six subsequent returns. Winnecke, however, in 1858, at its seventh return, picked it up accidentally. Mechain's comet of 1790, with a period of 13.8 years, must have returned in 1803, 1817, 1830 and 1844, but it eluded re-observation until Tuttle recovered it in January 1858.

Most of the periodical comets at perihelion are outside the earth's orbit, and hence it follows that they escape observation unless the earth is on the same side of the sun as the comet. As an instance of the favourable presentation of a comet, that of 1894 I. may be alluded to. Its perihelion is 14 millions of miles outside the earth's orbit, and is in longitude $130\frac{1}{2}^\circ$, which it reached on February 9. Now the earth was in longitude 140° at the same time, so the comet was nearly in opposition and visible under the most favourable circumstances during the whole night.

Some comets, as Tempel-Swift's, are only perceptible at alternate returns; others are not well visible except at intervals after two, three, or four returns.

Another circumstance which will prevent our exhausting the discovery of these objects, is that the planet Jupiter frequently introduces disturbances into their motions, and possibly into the physical conformations of the short period comets. He appears, also, capable of effecting new captures, and thus bringing these bodies into permanent membership of the solar system. The Jovian family of comets is already a numerous one, and is probably increasing, though some of the objects which owe allegiance to Jupiter are in process of disruption and gradual dispersion, and seem likely in the end to lose their visible character, as compact bodies, to form meteoric streams with the residue of their material. Biela's comet has not been seen for forty-five years, though it ought to have returned six times in that interval, and was one of the earliest discovered, as well as one of the best known, of the periodical comets. It will probably never be seen again as a comet, though its associated meteors will be displayed in November 1898, and in future years at periods conforming with the time of revolution of the parent comet.

We must, however, not be too hasty in assuming the collapse of known comets, for experience has taught us that they may reappear when least expected. The visible return of De Vico's comet of 1844, after being unseen for fifty years, and of Pons's comet of 1819, after an invisibility of thirty-nine years, shows us what is possible. Brorsen's comet, which escaped observation in 1884, 1890 and 1895, is supposed to have disappeared like Biela's, but a small comet may be swept up at some future time which will exhibit a similarity of elements to that of the missing Brorsen sufficient to prove the actual identity of the two objects.

The distribution of the aphelia of periodical comets near the orbits of the major planets is not the least interesting feature connected with these bodies. But it is perhaps a little remarkable that though Jupiter's family has enormously increased in recent years, yet the other groups have received very few, if any, additions, though a large number of new comets have been discovered.

W. F. DENNING.

THE PROGRESS OF THE STEAM TURBINE.

THE earliest notices of heat engines are found in the "Pneumatics" of Hero of Alexandria, which dates from the year 200 B.C. One of the steam or motive power engines there mentioned is the *Æolipiles*, a steam reaction engine consisting of a spherical boiler pivoted on a central axis beneath which is placed a flame. The steam escapes by bent pipes facing tangentially in opposite directions at opposite ends of a diameter perpendicular to the axis.

economy the turbine was made what is called compound, or, in other words, a series of successive turbine wheels were set one after the other on the same spindle, so that the steam passing through them one after the other, the fall in pressure being spread over the series of turbines should be gradual, and the velocity of the steam nowhere more than was desirable for obtaining a high efficiency for each turbine of the series.

The turbine motor consists of a cylindrical case with rings of inwardly projecting guide blades, within which revolves a concentric shaft with rings of outwardly pro-

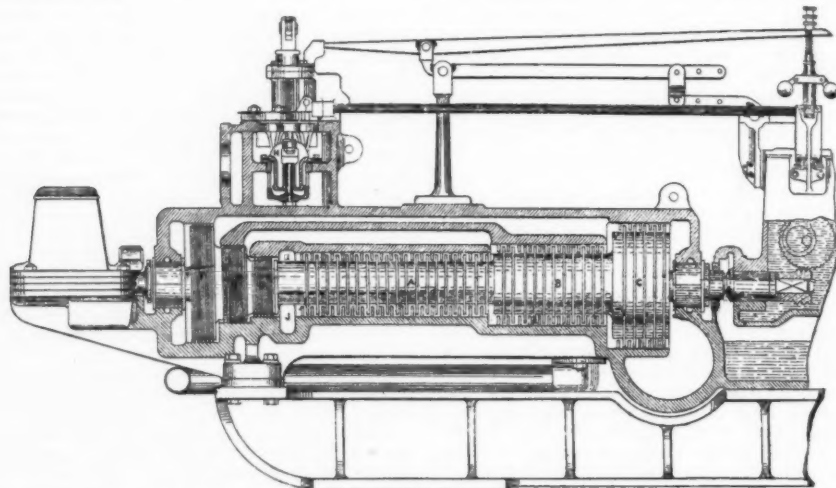


FIG. 1.—Sectional view of a Compound Turbine, showing the turbine blades and also the steam admission valve and bearings, as well as the governor gear.

The globe revolves by reaction of the escaping steam, just as a Barker mill is driven by escaping water.

No practical or useful steam engine appears to have been made on this or any analogous principle till the year 1884, though many attempts seem to have been made on more or less crude lines; meantime the piston engine of Papin, Savery, Newcomen, and Watts has been developed during the last 200 years, and by its general use has revolutionised the means of transit and tended to vastly increase the productive power of labour generally.

The want of a fast running engine for driving dynamos presented an immediate field for the application and development of a suitable steam turbine engine. The advantages of a steady running engine having no reciprocating parts, of small size and extreme lightness, were sufficiently obvious provided that fairly economical results as to steam consumption could be realised.

The highly economical results obtained from water turbines gave hopes that, provided suitable conditions could be arranged, similar efficiency would be obtained with steam as with water; and assuming this to be possible it would naturally follow, after taking all other losses into account, that the steam turbine would be more economical in steam than the piston engine.

These possibilities, and the interest of applying a practically new method for motive-power purposes, led the Hon. C. A. Parsons to build an experimental engine of ten-horse power coupled directly to a dynamo.

For practical reasons it was, however, necessary to keep the speed of rotation of the turbine as low as possible, and also to construct the dynamo to run as fast as possible, so as to couple the turbine directly to it; and in order to obtain the necessary conditions for steam

jecting blades. The rings of blades on the cylinder nearly touch the shaft, and the rings of blades on the shaft lie between those on the case, and nearly touch the case. It will be seen, on referring to Fig. 1, that there is left between the shaft and the case an annular space, which is filled with alternate rings of fixed and moving

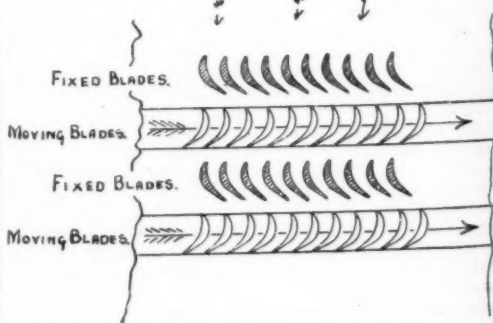


FIG. 2.—Section through blades in annular space between shaft and casing showing relative positions of fixed guide blades and moving blades. The three arrows at the top indicate the direction of motion of the entering steam.

blades. Fig. 2 shows one form of blades which is used. Steam entering at J (Fig. 1) passes first through a ring of fixed guide blades, by which it is projected in a rotational direction upon the succeeding ring of moving blades, imparting to them a rotational force; it is then thrown back upon the succeeding ring of guide blades, and the

reaction increases the rotational force. The same process takes place at each of the successive rings of guide and moving blades. The energy to give the steam its high rotational velocity at each successive ring is supplied by the drop in pressure, and the steam expands gradually by small increments. In a moderate-sized turbo-motor there may be from thirty to eighty successive rings, and when the steam arrives at the last ring the expansion has been completed. On the left side of the steam inlet *J* are the driving or rotating pistons, which are fixed to and rotate with the shaft. On their outsides are grooves and rings, which project into corresponding grooves in the case. By means of the thrust bearing of the motor the longitudinal position of the shaft is adjusted and grooves and projecting rings kept nearly touching, so as to make a practically tight joint. The object of these pistons is to steam balance the shaft and relieve end pressure on the thrust bearing. Fig. 3 shows a 350 kilowatt turbo-alternator, thirteen of which size are now at work in the London stations.

With compound condensing turbines a steam efficiency comparable with the best compound or triple expansion condensing engines was at length reached, and it was

of 32½ knots, and the maximum speed so far obtained has been about 35 knots.

It is anticipated that this turbine engine can be successfully applied to all the faster class of vessels, including those of the largest size; in fact, it appears that the relative advantages are greatest in the largest sizes.

NOTES.

THE new Government Laboratory, which has been about two years in course of erection, is now completed, and will be formally opened to-morrow (October 1). We hope to be able to give a description of the building in our next issue.

THE Paris correspondent of the *Times* states that an anniversary service was held on Tuesday at the Pasteur Institute in honour of the great investigator. A number of his disciples and the members of his family who are in Paris assembled in the crypt of the Institute at his tomb, and placed upon it garlands of flowers from the Garches gardens. The subscription for the Pasteur monument now exceeds 300,000 francs.

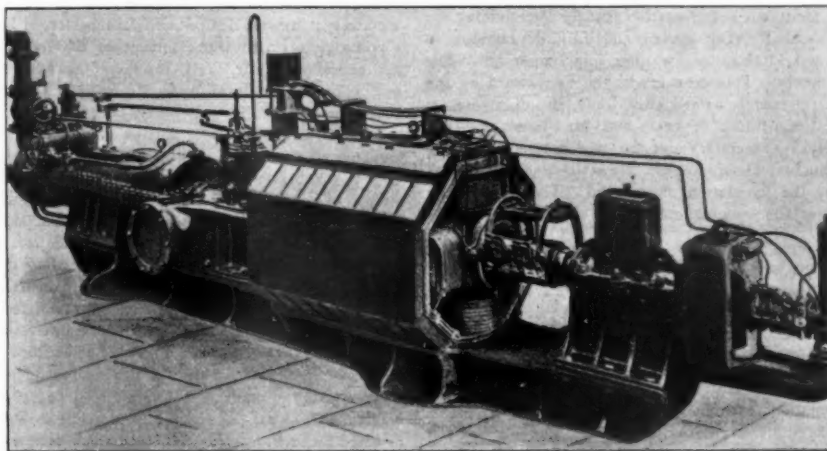


FIG. 3.—A 350-kilowatt Alternator and Turbine.

then resolved to test the application of the turbine to the propulsion of ships, for which purpose it seemed well suited, provided that as good an efficiency could be obtained from fast running screw-propellers as with ordinary ones, and to test the system it was determined to build the *Turbinia*, which is 100 feet in length, 9 feet beam, and 44½ tons displacement. One compound condensing turbine engine of 2000 I.H.P. was at first fitted, but it was found that long before this power was developed the screw began to tear the water, forming vacuous spaces and vortices behind the blades, and causing great loss of propulsive effect. The single large engine was then replaced by three separate ones, high pressure, intermediate pressure, and low pressure, each driving a screw shaft at the same speed of rotation as before; but the blade area was by these means trebled, and this trouble ceased. The efficiency of the screws approached closely to the best results of ordinary screws. The *Turbinia's* engines are similar to those for the driving of dynamos described, but they are necessarily larger and of lighter construction, and the expansion of the steam is carried to 170-fold at full speed. Prof. Ewing's tests have shown a consumption of 14½ lb. of steam per I.H.P. at a speed

AN epidemic of typhoid fever has broken out at Maidstone, Kent. More than nine hundred cases have been notified, and up to Tuesday night twenty-one deaths from the disease had occurred since the beginning of the outbreak. The epidemic is due to polluted water, and is confined to the area of the town supplied with water from springs at Farleigh, all of which have been condemned by the medical officer of health.

IT is much to be regretted that the splendid male Giraffe, presented to the Queen by the Chief Bethoen, of Bechuanaland, died so soon after reaching this country. The difficult task of bringing it home was entrusted by the Colonial Office to the Zoological Society, who selected for the work one of the most experienced men in Europe in moving large living animals—Herr Windhorn, of Alfeld. The Giraffe was led from Kanya to Lobatsi by road, and safely lodged at the railway station in a box, which had been specially constructed for it at Cape Town. It was placed on board the s.s. *Roslin Castle* (in which a free passage had been most liberally granted to it by Sir Donald Currie), and left Cape Town on September 1. The passage was a stormy one, and after the first week the Giraffe declined to eat anything but bread. A few days later it left off feeding altogether,

in spite of every attempt of its experienced keeper to induce it to eat. It was therefore, on reaching London, nearly dead from exhaustion, and only lived for half an hour after its arrival in the Regent's Park, where it was proposed to keep it for the winter. This event is the more to be lamented, as the fine young female already in the Society's Gardens (which was also brought to England from the Cape by Herr Windhorn) thus remains still without a mate, and there is at present little prospect of obtaining one.

AMONG the prizes awarded by the Institution of Civil Engineers for the session 1896-97 are the following:—The Howard prize of fifty guineas to Mr. H. Bauerman, in recognition of his work on the metallurgy of iron. For original papers presented to the institution, Telford medals, with premiums of books or instruments, to Messrs. H. A. Humphrey, for "The Mond Gas-Producer Plant and its Application"; to Colonel Penny-cuik, R.E., for "The Diversion of the Parivar"; to Mr. E. C. Shankland, for "Steel Skeleton Construction in Chicago"; to Mr. Dugald Drummond, for "High Pressure in Locomotives"; and to Mr. Thomas Holgate, for "The Enrichment of Coal Gas." George Stephenson medals and Telford premiums to Mr. Crutwell, for "The Tower-bridge Superstructure," and to Prof. Unwin, for "A new Indentation Test for Determining the Hardness of Metals." Watt medals and Telford premiums to Messrs. Hay and Fitzmaurice, for their joint paper on "The Blackwall Tunnel." This year marks the first award by the Institution of the medals named after Joule, the discoverer of the mechanical equivalent of heat, and Mr. James Forrester, whose long service as secretary and the care devoted by him to fostering the student class, have on his retirement been commemorated by the foundation of a medal. The presentation will be made at the opening meeting of the new session on November 2.

THE deaths are announced of Dr. August Mojsisovics, Edler von Mojsvar, professor of zoology and comparative anatomy in the University of Gratz; Mr. Theodore Lyman, honorary member of the National Academy of Sciences; and Dr. Welcker, for some years professor of anatomy in the University of Halle.

PROF. JOHN MILNE has shown us the photographic tracings of two well-marked earthquakes, recorded last week by his seismographs at Shide, in the Isle of Wight. The times of the disturbances are September 20, 7.30 p.m., and September 21, 5.30 a.m. The duration of each disturbance at Shide was about three hours, and the preliminary tremors extended over about forty minutes, from which facts Prof. Milne concludes that the place of origin was at least six thousand miles distant.

MR. N. L. BRITTON has been elected President, and Mr. J. C. Arthur Vice-President, of the Botanical Society of America for the coming year.

WE learn from the *Botanical Gazette* that the Smithsonian Institution, Washington, has undertaken an important work in bringing together all possible material bearing on the medicinal uses of plants in the United States. Dr. V. Havard is chairman of the commission for this purpose.

MR. WILLIAM WESLEY WOOLEN, of Indianapolis, has announced his intention of presenting to that city a tract of land, consisting of fifty-six acres, for the purpose of establishing a botanic garden and an ornithological preserve.

PROF. J. P. O'REILLY sends us some extracts from a work on Morocco ("An Account of the Empire of Morocco," by James Grey Jackson, 1814), containing an account of the use of olive oil as a remedy for a form of plague which depopulated West Barbary in 1799-1800. The oil was used to anoint the skin, either before or after infection. Prof. O'Reilly points out that

the ordinary olive oil of the Levant and of Spain is not the pure clarified oil we know of in this country, but a green and generally more or less rancid oil produced in a coarse way from all sorts of fruit, unsound as well as sound.

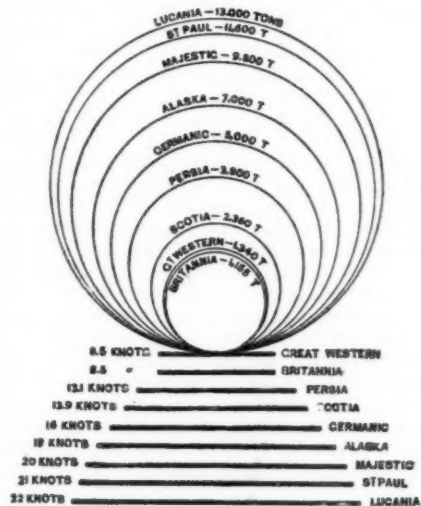
THE October number of *Science Progress* will contain articles on "Some Physiological Aspects of Hypnotism," by Prof. F. Gotch, F.R.S.; on "Artificial Flight," by Prof. G. H. Bryan, F.R.S.; on "Progress in the Study of Variation," by Mr. W. Bateson, F.R.S.; on "Blood and the Identification of Bacterial Species," by Dr. Grunbaum; on "The Fauna of the Great African Lakes," by Mr. J. E. S. Moore.

DURING the past summer full advantage has been taken of the facilities for research afforded by the Plymouth laboratory of the Marine Biological Association. Prof. Weldon has carried out an interesting experimental inquiry into the selective action of different conditions in the case of *Carcinus manas*. Mr. S. D. Scott has studied the physiology of excretion in certain Ascidians, Dr. Lubbock the anatomy of various fishes. Dr. G. Duncker, of Kiel, is at work upon the racial characteristics and variation of Pleuronectids and other fishes; Mr. Taylor, upon Polyzoa; Messrs. E. T. Brown and Jenkinson, of University College, London, upon Medusae and larval Crustacea respectively; Messrs. Bedford and Lanchester, of King's College, Cambridge, upon the development of *Myriothele* and general marine zoology. Mr. W. I. Beaumont has been studying more especially the Nudibranchiate Mollusca and Nemertinea, and some rare captures have rewarded his exertions, notably several specimens of *Hancockia* and large *Lomanotus*. Mr. Brebner, of University College, Bristol, and Mr. A. H. Church, of Oxford, have devoted much attention to the collection and study of marine algae. In spite of the inclemency of the weather during August, the steamboat *Busy Bee* has been in constant requisition throughout the summer. Under Mr. Holt's charge a prolonged visit was paid in July to Falmouth, where Mr. Rupert Vallentin and Mr. J. T. Cunningham assisted the staff, and much valuable material was accumulated. The rare dragonet *Callionymus maculatus* and the interesting Anthozoan *Gonactinia prolifera* were obtained during this cruise. Trawling expeditions under Mr. Holt have also been made to Exmouth and Dartmouth, in addition to the routine work in the neighbourhood of Plymouth. Mr. Garstang has returned from Toronto, and has resumed his investigation of the racial characters and variation of the mackerel, for which purpose a large number of fish has been received from H.M. Inspectors of Irish Fisheries. In connection with the food-supply and migrations of pelagic fishes, Mr. Garstang is also investigating the seasonal changes and distribution of the plankton, and has brought back with him two series of collections of the surface plankton of the North Atlantic, obtained during his recent voyages from Liverpool to Quebec via the North of Ireland, and from Philadelphia to Queenstown along the edge of the Gulf Stream. Interesting results are expected from the comparison of these collections of "pump-plankton." The Marine Biological Association's exhibit, which proved so attractive a feature of the recent fisheries exhibition at the Imperial Institute, has been returned to the laboratory, and has been temporarily set up again in the students' lecture-room.

PROF. R. C. CARPENTER, professor of engineering science in Cornell University, has (says *Engineering*) been conducting an elaborate set of experiments on bicycle friction which have led him to the conclusion that no form of gearing can possibly equal the best chain for efficiency and durability. With such the frictional loss has been found to be between $\frac{1}{2}$ and $\frac{3}{4}$ per cent. of the total power transmitted, this result being obtained with a chain which had previously been ridden more than 2000 miles with a rider weighing about 14 stone. With some other

chains less well constructed, a greater loss has been found, the friction lying generally between 2 and 5 per cent.; the maximum shown, even by an old chain which did not fit its sprocket properly, was under 10 per cent. No bevel gears as yet constructed give as good results as these, and Prof. Carpenter concludes that with even the best bevel-gear bicycles the loss must be four times as much as with the ordinary chain, and six times as much as with the best chain. Moreover, as has been previously pointed out, gear wheels to work well must be in very accurate adjustment with each other, whilst with a chain no such careful fitting is required.

THE current number of *The Engineering Magazine* contains an instructive illustrated article, by Mr. Ridgely Hunt, on fifty years of advance in marine engineering. The accompanying diagram, reproduced from our contemporary, shows at a glance the increase of tonnage and speed during the last half-century. In this period iron and steel have supplanted wood, and, says the author, "engines have advanced from simple to compound, and then to triple-expansion; so, too, have paddle-wheels been discarded for single-propellers and for twin-propellers; so, too, have single rectangular boilers with one flue, been replaced by several boilers, cylindrical, and with many tubes; so, too, have



jet condensers been transformed into surface condensers, and the steam pressures have been raised from 10 to 100 and 200 pounds to the square inch. The size of steamships has been multiplied twenty-fold, and the horse-power forty-fold. The speeds of the ships have been increased from 8 to 17 and 23 knots; and in every other respect has there been a like extraordinary evolution." How the conversions have been effected is briefly described in Mr. Hunt's interesting paper.

A VERY brilliant aurora observed on April 20 in lat. $47\frac{1}{2}^{\circ}$ S., by Captain M. W. C. Hepworth, was briefly described in our notes on June 24 (p. 183). Mr. T. F. Claxton, the director of the Royal Alfred Observatory, Mauritius, sends us an account of magnetic disturbances apparently connected with the aurora display. He says that on the day of the aurora a rather large magnetic disturbance was recorded at the observatory. "From June 20d. 9h.-19h. the horizontal force decreased '01578 m.m.s. units. From 20d. 12½h.-19h. the vertical force increased '00336 m.m.s. units, and the declination, from 20d. 9½h.-13h., decreased 9'2, and from 13h. to 19h. increased 7'0. The most active period was from 20d. 17h.-20h. The magnets

were quiet from 21d. 0h.-23d. 10h. 16m., when a sudden decrease of horizontal force, vertical force, and declination occurred to the extent of '00258, '00056 m.m.s. units, and 1'0 respectively. In horizontal force the decrease continued till 23d. 21½h., and amounted to '01204 m.m.s. units, while the disturbance in vertical force was very small."

THE report of the Central Meteorological Office of France for the year 1896, shows a large amount of work performed, and is very creditable to the staff of that institution. One of the principal services rendered consists in predicting the approach of storms for one or two days in advance. Out of thirty-four storms which reached the French shores, thirty-one, or 91 per cent., were foretold. This satisfactory result is, to a considerable extent, due to the fact that the great majority of these disturbances cross the British Isles, notice of which is regularly telegraphed to Paris by the Meteorological Council. The number of telegraphic reports received daily amounts to 167, some of which are from America, and include observations received from the fast trans-Atlantic steamers. In the department of climatology, reports are received from 211 places, in addition to a very large number of rainfall stations, and the results and discussions are published in three large quarto volumes yearly. In addition, monthly returns are received from about fifty foreign stations, as well as a large number of ships' logs. Particular attention is also paid to the collection of observations made at mountain stations, as well as by means of balloons and kites. The observation of clouds has formed a special feature during the past year; between July 1896 and April 1897, M. Teisserenc de Bort has taken no less than 2500 photographs of clouds at his observatory at Trappes, and by this means the heights of 750 have been determined.

WE have already had occasion to direct attention in our columns to the ingenious experiments conducted by Messrs. Nuttall and Thierfelder on the possibility of animal life being carried on in the absence of bacteria in the digestive tract; the third memoir on this subject by these gentlemen has now appeared in the *Zeitschrift für physiologische Chemie*, Bd. xxiii., 1897. In their previous experiments guinea-pigs were selected as subjects for experiment, but it not unnaturally occurred to the authors that chickens would be more suitable, inasmuch as they might remove some of the great difficulties which attend the procurement of the former animals in an aseptic condition from their birth. Accordingly, a few hours before the chicken was due to be hatched some eggs were carefully washed outside with corrosive sublimate and hydrochloric acid, to remove all external germ-life, and were then placed in the sterile apparatus devised by the authors, and employed in their previous experiments. But, despite the most careful manipulations, bacteria obtained access to the apparatus and spoil the observations. There was only one conclusion to be drawn, which was that the egg-shells of the hatched chickens were responsible for the mischief. Accordingly careful examinations of eggs were made, with the result that in every instance bacteria were found on the inside of the shell. The authors conclude that bacteria are present in the oviduct before and during the formation of the shell, and become attached to the membrane of the shell. This unlooked-for and, from the experimental point of view of the investigators, unpropitious discovery has led to the abandonment of chickens for the purpose of these observations, and the authors do not announce any further intention of pursuing their interesting researches.

CULTIVATORS in many regions of the globe will be interested in what appears to have been a successful series of locust-destroying experiments carried out in Natal, a report of which has been published in that colony as a Government notice. From a note in the *Times*, it appears that all attempts to suppress the

locust scourge there have proved only partially successful, with the exception of the plan of poisoning with arsenic, which, it is asserted, has met with absolute and unqualified success. The mixture used is prepared by heating four gallons of water to boiling point, and then adding 1 lb. of caustic soda. As soon as this is dissolved, 1 lb. of arsenic is added, after which the liquid is well stirred and boiled for a few minutes, care being taken that the fumes are not inhaled. When required for use, half a gallon of the liquid is added to four gallons of hot or cold water, with 10 lb. of brown sugar. A still better preparation is made by adding half a gallon of the poisonous liquid to five gallons of treacle. Maize-stalks, grass, &c., dipped in the mixture, are placed along the roads and in the fields, and the material can also be splashed with a brush upon anything which the locusts are known to have a liking for. Attracted by the odour of the sugar or treacle over a distance of as much as 100 yards, the locusts will eat of the mixture and die. These are eaten by other locusts, and in a few days' time the ground may become strewn with the dead bodies of the insects. With ordinary care no risk of poisoning any human being is incurred, whilst the small quantity of the material on a piece of grass or maize-stalk is said to be insufficient to injure stock of any kind—fowls have been known to feed without injury on the arsenic-destroyed locusts. The evidence adduced indicates that "hoppers," however numerous, can be destroyed in a few days, and the crops thus saved from their ravages.

Petermann's Mittheilungen promises accounts of much important geographical work recently done in Asia. M. de Déchy has explored some interesting and little-known districts of the Caucasus. Dr. Sven Hedin is to publish (in the *Mittheilungen*) a series of articles on the Mustagh-ata, the Deserts of Eastern Turkestan, the Lob-Nor problem, and on Northern Tibet. The Hungarian geologist, Dr. Eugen von Chonokny, has made some progress with an investigation of the hydrography of the great plain of China.

SIGNOR FRANCESCO CHINIGO contributes, to the *Bollettino della Società Geografica Italiana*, a note on the salt deposits of Lungro, on the slope of the Calabrian Apennines. The deposits have been worked to a depth of 220 metres, and probably extend to a much greater distance below the surface. Analyses show a composition of 97.7 per cent. of sodium chloride, the principal other constituent being sodium sulphate. The output is at present much restricted, chiefly on account of deficient railway communication, but there is no real obstacle to prevent these deposits supplying the whole of Italy with salt of the highest quality.

THE *Zeitschrift der Gesellschaft für Erdkunde zu Berlin* contains a short summary, by Dr. Carl Sapper, of available information about the first campaigns of the Spaniards in Northern Central America. The material at hand is in many respects unpromising, many accounts are directly contradictory, and there are traces of much priestly interference with the documents; but a good deal can, nevertheless, be made out with fair chances of accuracy. Dr. Sapper shows on a sketch map the courses of Francisco Hernandez (1517), of Juan de Grijalva (1518), and of Ferdinand Cortes (1519) by sea, and the land routes of Ferdinand Cortes (1524-25), of Pedro de Alvarado (1524), of Luis Marin (1523?), and of Adelantado Francisco de Montejo (1526-27); and shows hypothetical boundaries of the great kingdoms of Mayapan and Quiché, which fortunately for the Spaniards came to an end before their day.

ATTENTION has been drawn by Dr. G. A. Dorsey (*American Anthropologist*, x. p. 169) to the frequency of Wormian bones in the coronal suture in artificially deformed skulls of the Kwakiutl Indians of Vancouver Island. He explains their

occurrence by bandaging in early life, and he finds that the percentage of frequency becomes the greater as we ascend the scale of length of the cranium due to artificial elongation, and just in direct proportion to a deep well-defined groove behind the coronal suture. The long bones of the Kwakiutl and Salish Indians of British Columbia have also been studied by Dr. G. A. Dorsey in the same journal. The radio-humeral index is 75.5; the lengthening may be due to intermixture with Indians of the east or south. The tibio-femoral index is 79.1, the intermembral index is 70.7, and the femero-humeral index is 72.8. These indices approach very closely, and indeed often equal, those which have been determined for the Eskimos, the Samoyeds, and the Lapps.

ATTENTION has previously been drawn (*NATURE*, vol. liv. p. 404) to the good work in Indian anthropology that is being done by Mr. Edgar Thurston, the superintendent of the Madras Government Museum. The second volume of the Museum *Bulletin* opens with an account of the Badagas and Irulas of the Nilgiris, the Paniyans of Malabar and the Kuruba or Kurumba; there are numerous tables of measurements, and seventeen plates. The Paniyans are a dark-skinned tribe short in stature (1574 mm., 5 ft. 2 in.), dolichocephalic (74), with broad noses (min. 83.7, max. 108.6, av. 95.1), and curly hair. The common belief that they are of African origin is erroneous. They are wholly uneducated, and do not associate with other tribes. A short account is given of the customs and manner of living of this primitive Dravidian tribe. The other tribes mentioned by the author also exhibit Dravidian characters to a greater or less extent. In the interesting summary which closes this small but valuable memoir the author draws attention to the rapid modification of the natives through contact with the European, and to the need for immediate ethnographical investigations before it is too late. He says: "I was lately shocked by seeing a Toda boy studying for the third standard in Tamil, instead of tending the buffaloes of his mand. The Todas, whose natural drink is milk, now delight in bottled beer and a mixture of port wine and gin. Tiles and kerosine tins are employed instead of the primitive thatch. A Bengali babu, with close-cropped hair and bare head, clad in patent-leather boots, white socks, dhuti, and conspicuous unstarched shirt of English device; a Hindu or Parsi cricket eleven engaged against a European team; the increasing struggle for small-paid appointments under Government—these are a few examples of changes resulting from the refinement of modern civilisation."

THE first part of a Report by M. Ch. Rabot (International Commission on Glaciers) on the variation in the length of glaciers in the Arctic regions, has been published in the *Arch. Sci. Phys. et Nat., Geneva*. All available evidence is here collected from many scattered sources, and though the evidence is admittedly imperfect, it enables some interesting conclusions to be drawn. There is no sign of a general retreat corresponding to that of the Alpine glaciers after 1850. In Greenland the ice seems to be stationary at a maximum now. In Iceland, the eighteenth century was marked by a general increase, interrupted by a partial decrease, only to be followed by a very extensive advance which has lasted through most of the nineteenth century. A slight retreat began in the north of the island about 1855-60, and twenty years later in the south; but this is not comparable with the marked retreat in the Alps. Grinnel Land and Jan Mayen are also dealt with in this instalment of a valuable report.

THE double number of *Spelunca*, which completes the third volume, maintains the high standard of its predecessors. Among other articles are one on the Kentucky Mammoth Cave, and one on the caves of County Leitrim.

MESSRS. A. GALLINKAMP AND CO., makers of chemical apparatus, wish it to be known that, in the new premises to which they have just removed, they propose to exhibit in their show-room examples of new instruments described in scientific periodicals, and of apparatus kept in stock.

A BIOGRAPHY and an account of the botanical labours of the late Prof. Julius Sachs, by Prof. Goebel, appears in the pages of *Flora*; and one of the late Fritz Müller, by Prof. Ludwig, in the *Botanisches Centralblatt*. Each memoir is accompanied by a copious bibliography.

ANOTHER new botanical journal is announced from America, the first number to appear on October 1. It is to be named *The Plant World*, and will be an illustrated monthly journal of popular botany. "It will," says the *Botanical Gazette*, "present the facts of plant-life in simple popular language, and aim to interest those who have no inclination for a systematic course of study. The purpose is to be scientific, but not technical." The editor will be Dr. J. F. Knowlton, of the U.S. National Museum.

AMONG papers on physiological botany recently received from America are "The Curvature of Roots" by Mr. D. T. McDougal, and "The Role of Water in Growth" by Mr. C. B. Davenport. In the former the author points out that the curvatures of stems are not due to the same causes as those of tendrils or of many roots. The curvature of roots is due to the excessive elongation of the internal layers of the cortex of the side which becomes convex. The development and organisation of irritability in roots has been widely different from that in stems. The organs of the irritable mechanism of roots exhibit a physiological rather than a morphological differentiation.

THE additions to the Zoological Society's Gardens during the past week include a Badger (*Meles taxus*) from Worcestershire, presented by Mrs. Cheape; a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mrs. B. Hudson; a Red and Yellow Macaw (*Ara chloroptera*) from South America, presented by Mr. J. W. Drysdale; a Peregrine Falcon (*Falco peregrinus*), British, presented by Major Hawkins Fisher; a Lesser Sulphur-crested Cockatoo (*Cacatua sulphurea*) from Moluccas, presented by Mr. John Paget; a Crowned Lemur (*Lemur coronatus*) from Madagascar, two Korin Gazelles (*Gazella rufifrons*, ♂ ♀) from Senegal; an Alexandrine Parrakeet (*Palaornis alexandri*) from India, deposited; two Common Sandpipers (*Tringoides hypoleucis*), European, purchased.

OUR ASTRONOMICAL COLUMN.

BOND'S COLLECTED WORKS.—It is stated in *Science* that, at the request of the daughters of George Bond, Prof. Holden, Director of the Lick Observatory, has undertaken to arrange the manuscript material in their hands in an orderly form. The work will be entitled "Memorials of William Cranch Bond, Director of the Harvard College Observatory, 1840-59, and of his Son, George Phillips Bond, Director of the Harvard College Observatory, 1859-65," and will be published by Messrs. C. A. Murdock and Co., San Francisco, and by Messrs. Lemcke and Büchner, New York City. The book will be well illustrated. It is hoped, by the kindness of Prof. E. C. Pickering, to reproduce two fine steel engravings of the Great Comet of 1858 and of the nebula of Orion, from the plates of the *Annals* of the Harvard College Observatory.

ECLIPSE EXPEDITION OF THE LICK OBSERVATORY.—We learn from the Publications of the Astronomical Society of the Pacific, that the Lick Observatory expedition to observe the forthcoming solar eclipse will consist of Prof. Campbell and volunteer assistants. The expenses of the expedition will be met from a fund provided by the late Colonel C. F. Crocker.

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The programme will include spectroscopic and photographic work, and an equipment will be taken to obtain the following results, among others:—Photographs of the spectrum of the reversing layer; spectrum photographs having for their special object the determination of the velocity of rotation of the corona; photographs of the corona on a large scale (40 feet long), on the plan employed by Prof. Schaeberle in Chile; photographs of the corona with a portrait lens; photographic photometry of the corona.

A REMARKABLE BINARY STAR.—Recent observations leave practically no room for doubt that the close double star β 883 = Lalande 9091 (R.A. = 4h. 44m. 33s., Decl. + 10° 52', Mags. 7.8 and 8), has the shortest period of any known binary. The star was discovered by Mr. Burnham in 1879, and Schiaparelli made a number of measures of it between 1887 and 1895, and upon combining these observations with other measures, Dr. T. J. J. See was forced to the conclusion that the period was only a few years. Further considerations give support to this view, and now Dr. See (*Monthly Notices*, R.A.S., June 1897), from a discussion of the whole of the facts of observation, concludes that the period is only 5.5 years.

The elements of the orbit are given as follows:—

$$\begin{aligned} P &= 5.5 \text{ years} & a &= 0''.621 \\ T &= 1896.40 & \Omega &= 20^\circ 6' \\ e &= 0.760 & i &= 82^\circ 52' \\ & & \lambda &= 273^\circ 83' \end{aligned}$$

Apparent orbit:—

$$\begin{aligned} \text{Length of major axis} &= 0''.67 \\ \text{Length of minor axis} &= 0''.16 \\ \text{Angle of major axis} &= 19^\circ 5' \\ \text{Angle of periastron} &= 318^\circ 0' \\ \text{Distance of star from centre} &= 0''.07 \end{aligned}$$

Referring to this remarkable object, Dr. See says:—

"The discovery of an object revolving in a period of 5.5 years is an achievement of some philosophic significance in the history of double-star astronomy. In the time of Sir John Herschel the most rapid of known binaries was ϵ Herculis, with a period of 35 years. Twenty years ago the remarkable object 42 Comæ Berenices had reduced the shortest period to about 25 years, and in 1887 δ Equulei brought it down to 11.5 years. α Pegasi (β 989) has since been shown to revolve in a similar period.

In β 883 we have for the first time a visible binary with a period fairly approaching those of the spectroscopic binaries recently discovered, and we seem assured that at last a link has been found connecting the two classes of objects. It is probable that other stars will disclose even shorter periods, for there is no reason why there should not be close doubles with periods of a single year or less. It will be an interesting object of future research to fill in the intervening steps between visible binaries with periods of a few years and the spectroscopic binaries revolving in a few days or months.

"The more critical inquiry into the motion of close doubles will commend itself to the attention of double-star observers with great telescopes, and, on the other hand, it may be hoped that the study of the relative motion in line of sight of the components of binaries like β 883 will be taken up by some of our great observatories equipped with powerful spectroscopic appliances."

FORTHCOMING BOOKS OF SCIENCE.

MR. EDWARD ARNOLD'S list contains:—"Higher Algebra," by Dr. R. Lachlan; "The Elements of Trigonometry," by Dr. R. Lachlan; "Analytical Geometry," by Dr. R. Lachlan; "The Elements of Euclid," Books III., IV. and VI., by Dr. R. Lachlan; "Dynamics for Engineering Students," by Prof. W. E. Dalby; "Elementary Natural Philosophy," by Alfred Earl; "An Elementary Chemistry," by W. A. Shennstone; "Physical Chemistry," by Dr. Alexander Scott; "Practical Chemistry," by Dr. E. H. Cook; "A Manual of Physiology," by Dr. Leonard Hill; "A Manual of Botany," by David Houston; Arnold's Practical Science Manuals: "Steam Boilers," by George Halliday; "Agricultural Chemistry," by T. S. Dymond; "Electric Traction," by Ernest Wilson; "Lectures on Sound, Light, and Heat," by Dr. Richard Wormell, new edition.

Messrs. Baillière, Tindall, and Cox's forthcoming books in-

clude:—Hand-Atlas Series: "Essentials of Bacteriology," by Profs. Lehmann and Neumann (illustrated); "Atlas of Fractures and Dislocations," by Prof. H. Helferich; "A Manual on Diseases of the Heart," by Sir Wm. Broadbent, Bart., F.R.S.; "The Röntgen Rays in Medicine and Surgery: a Manual for Practitioners and Students," by Dr. David Walsh, illustrated.

Messrs. Bliss, Sands, and Co. promise:—The Progressive Science Series: "Earth Structure," by Prof. Geikie, F.R.S.; "Volcanoes," by Prof. Bonney, F.R.S.; "The Groundwork of Science," by Dr. St. George Mivart, F.R.S.; "Vertebrate Palaeontology," by Prof. Cope; "Science and Ethics," by M. Berthelot; "The Country Month by Month," by J. A. Owen and Prof. G. S. Boulger, a re-issue, in four quarterly volumes: Spring, Summer, Autumn, Winter, illustrated.

In Messrs. William Blackwood and Sons' list we find:—"A Sketch of the Natural History (Vertebrates) of the British Islands, with a bibliography of over two hundred works relating to the British Fauna, and a List of Field Clubs and Natural History Societies at present existing in the United Kingdom," by F. G. Afalo, illustrated; "Wild Traits in Tame Animals: being some familiar Studies in Evolution," by Dr. Louis Robinson, illustrated; "A Manual of Agricultural Botany," from the German of Dr. A. B. Frank, translated by Dr. John W. Paterson, illustrated; "Things of Everyday: a Popular Science Reader on some Common Things," illustrated; "Introductory Text-Book of Meteorology," by Dr. Alexander Buchan, new edition, illustrated; "Dr. Mackay's Elements of Physiography," rewritten and enlarged, illustrated; "Page's Introductory Text-Book of Geology," new edition, revised and enlarged by Prof. Lapworth, F.R.S.; "Page's Advanced Text-Book of Geology, Descriptive and Industrial," with engravings and glossary of scientific terms, new edition, revised and enlarged by Prof. Lapworth, F.R.S.; "Introductory Text-Book of Zoology, for the Use of Junior Students," by Prof. Henry Alleyne Nicholson, F.R.S., new edition, revised and enlarged, illustrated.

The Cambridge University Press announces:—"The Collected Mathematical Papers of the late Arthur Cayley, F.R.S." (to be completed in thirteen volumes), vols. xii. and xiii.; "The Scientific Papers of John Couch Adams, F.R.S." vol. ii., edited by Prof. W. G. Adams, F.R.S., and R. A. Sampson; "The Theory of Groups of a Finite Order," by Prof. W. Burnside, F.R.S.; "A Treatise on Universal Algebra, with some applications," by A. N. Whitehead. Vol. i. contains the general principles of algebraic symbolism, the algebra of symbolic logic, the calculus of extension (*i.e.* the algebra of Graßmann's Ausdehnungslehre), with applications to projective geometry, to non-Euclidean geometry, and to mathematical physics; "A Treatise on Octonions: a development of Clifford's Bi-Quaternions," by Prof. Alexander McAulay; "A Treatise on Spherical Astronomy," by Prof. Sir Robert S. Ball, F.R.S.; "A Treatise on Geometrical Optics," by R. A. Herman; "An Elementary Course of Infinitesimal Calculus, for the use of Students of Physics and Engineering," by Prof. Horace Lamb, F.R.S.; "Theoretical Mechanics: an introductory Treatise on the Principles of Dynamics, with numerous applications and examples," by A. E. H. Love, F.R.S.; "The Works of Archimedes," edited in modern notation, with introductory chapters, by Dr. T. L. Heath; "The Steam Engine and other Heat Engines," by Prof. J. A. Ewing, F.R.S.; "Collected Mathematical Papers," by Prof. P. G. Tait; "Crystallography," by Prof. W. J. Lewis; "Geology," by J. E. Marr, F.R.S.; Cambridge Natural Science Manuals, Biological Series—"Fossil Plants: a Manual for Students of Botany and Geology," by A. C. Seward, in two volumes; "Vertebrate Palaeontology," by A. S. Woodward; "Handbook to the Geology of Cambridgeshire," by F. R. Cowper Reed; Physical Series—"Electricity and Magnetism," by R. T. Glazebrook, F.R.S.; "Sound," by J. W. Capstick.

The list of Messrs. Georges Carré et C. Naud, of Paris, includes:—"Leçons de Physiologie," by Prof. R. Dubois, illustrated; "Les Cancers épithéliaux," by Dr. Fabre-Dormergue, illustrated; "Manuel d'Analyse chimique appliquée à l'examen des produits industriels et commerciaux," by Prof. E. Fleurent, illustrated; "Manuel de Chirurgie orthopédique," by A. Hoffa, traduit de la 2^e édition allemande, par M. Barrozi, illustrated; "Leçons de thérapeutique et matière médicale: Sérothérapie, Opiothérapie," by Prof. L. Landouzy, illustrated; "Traité d'Anatomie comparée et de Zoologie, 1891-92, Ouvrage traduit de l'allemand par Prof. G. Curtel, by Prof. Lang, tome ii. (1^{re} fascicule): Mollusques; (2^e fascicule): Echinodermes; "Le

torticolis et son traitement," by M. Redard, illustrated; "Leçons d'optique physiologique," by M. Tscherning, illustrated.

The list of Messrs. Cassell and Co., Ltd., contains:—"Cassell's Family Doctor," by a Medical Man, illustrated; "With Nature and a Camera, being the Adventures and Observations of a Field Naturalist and an Animal Photographer," by Richard Kearton, illustrated by a special frontispiece, and about 150 pictures from photographs taken direct from nature, by Cherry Kearton; "Applied Mechanics," by Prof. John Perry, F.R.S., illustrated; "Familiar Wild Flowers," by F. E. Hulme, coloured plates, popular edition, complete in five vols.; "Familiar Garden Flowers," by F. E. Hulme, coloured plates and descriptive text by Shirley Hibberd, popular edition, complete in five vols. (new edition); "The Story of the Heavens," by Prof. Sir Robert S. Ball, F.R.S., illustrated, popular edition; "The Story of the Sun," by Prof. Sir Robert S. Ball, F.R.S., illustrated, cheap edition; "The Year-Book of Treatment (1898)"; "Science for All," edited by Dr. Robert Brown, assisted by eminent scientific writers, illustrated, complete in five vols., cheap edition; new volume of "Work" Handbooks: "Cycle Building and Repairing," illustrated; "Electricity in the Service of Man," revised by Dr. R. Mullineux Walmsley, illustrated, new and cheaper edition; "Cassell's Natural History," edited by P. Martin Duncan, F.R.S., illustrated, cheap edition, complete in three double vols.; "Cassell's New Technical Educator," cheap edition, complete in six vols.

Messrs. Chapman and Hall, Ltd., announce:—"What is life? or, Where are we? What are we? From whence did we come? And whither do we go?" by Frederick Hovenden, illustrated; "Physics, experimental and theoretical, an elementary treatise, mechanics, hydrostatics, pneumatics, heat, and acoustics," by Dr. R. H. Jude and H. Gossin, illustrated.

Among Messrs. J. & A. Churchill's announcements we find:—"A Manual of Diseases and Injuries of the Eye," by W. H. H. Jessop; "The Means by which the Temperature of the Body is maintained in Health and Disease, being the Croonian Lectures for 1897," by Dr. Hale White; "Economics, Anaesthetics, and Antiseptics in the Practice of Midwifery," by Haydn Brown; the second edition, enlarged, of Dr. Thin's "Treatise on Psoriasis, or 'Sprue'"; the second edition of "The Analyst's Laboratory Companion," by Alfred E. Johnson; the third edition of Mr. Hartridge's "Manual for Students on the Ophthalmoscope"; the third edition of Dr. Starling's "Elements of Human Physiology"; the sixth edition of "The Theory and Practice of Surgery," by W. J. Walsham; the eighth edition of Dr. Fenwick's "Student's Guide to Medical Diagnosis"; the eleventh edition of McHeath's "Manual of Minor Surgery and Bandaging."

The Clarendon Press will publish:—G. Claridge Druce's "Flora of Berkshire," dedicated by permission to Her Majesty the Queen; "An Account of the Herbarium of the University of Oxford"; and "A Book for Beginners in Geometry," by Prof. G. M. Minchin, F.R.S.

The list of Mr. Engelmann, of Leipzig, comprises:—"Arbeiten des physikalisch-chemischen Instituts der Universität Leipzig aus den Jahren 1887 bis 1896," gesammelt und herausgegeben von Prof. Wilhelm Ostwald, Vier Bände, Erster Band: (1) Allgemeines, (2) Die elektrische Leitfähigkeit gelöster Stoffe, (3) Die Dissociation der Säuren, (4) Die Dissociation der Basen, Zweiter Band: (5) Bestimmung von Molekulargewichten, (6) Das homogene Gleichgewicht, (7) Das heterogene Gleichgewicht, (8) Reaktionsgeschwindigkeit, Dritter Band: (9) Kontaktpotentiale, (10) Theorie der Kette, (11) Anwendung der Theorie der Kette, (12) Polarisation, Vierter Band: (13) Innere Reibung und Diffusion, (14) Optische Verhältnisse, (15) Thermische u. Volumverhältnisse, (16) Physikochemische Untersuchung einzelner Stoffgruppen, Verschiedenes; "Betrachtungen über die Farbenpracht der Insekten," by Brunner v. Wattenwyl, illustrated; "Das Wachstum des Menschen, Anthropologische Studie," by Dr. Franz Daffner; "Tafeln und Tabellen zur Darstellung der Ergebnisse spektroskopischer u. spektrophotometrischer Beobachtungen," by Prof. Th. W. Engelmann; "Kollektivmasslehre," by Gustav Theodor Fechner, Im Auftrage der Königl. Sächsischen Gesellschaft der Wissenschaften herausg. von Gottl. Friedr. Lipps; "Das Verhältniss der experimentellen Bakteriologie zur Chirurgie, Antrittsvorlesung, gehalten am 10 Juli 1897 in der Aula der Universität Leipzig, by Paul Leopold Friedrich; "Die Begriffe Phänomenon und

Noumenon in ihrem Verhältniss zu einander bei Kant. Ein Beitrag zur Auslegung und Kritik der Transcendental-philosophie," by Dr. George Dawes Hicks; "Der tägliche Wärmeumsatz im Boden und die Wärmestrahlung zwischen Himmel und Erde," by Theodor Homén; "Ein Beitrag zu einer sicheren Behandlung von Rachen-Diphtherie und Scharlach ohne Serum," by Dr. F. Lueddeckens; "Die wissenschaftlichen Grundlagen der analytischen Chemie, Elementar dargestellt," by Prof. W. Ostwald, Zweite vermehrte Auflage; "Pflanzenphysiologie, Ein Handbuch des Stoffwechsels und Kraftwechsels in der Pflanze," by Prof. W. Pfeffer, Zweite ganz umgearbeitete Auflage, Erster Band: Stoffwechsel; "Darwin und nach Darwin, Eine Darstellung der Darwinischen Theorie und Erörterung Darwinischer Streitfragen," by Dr. George John Romanes, F.R.S., iii. Band: Darwinische Streitfragen, Isolation und Physiologische Auslese. Mit Bewilligung des Herausgebers aus dem Englischen übersetzt von Dr. B. Nöldeke, Mit d. Bildniss v. Rev. J. Gulick; "Zur Psychologie des Erkennens, Eine biologische Studie," by Dr. Gustav Wolff.

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LONG RANGE TEMPERATURE AND PRESSURE VARIABLES IN PHYSICS.¹

METHODS OF PYROMETRY.

THE endeavour to provide suitable apparatus for high temperature measurement is one of long standing. The student of the subject is fairly overwhelmed with the variety of devices which have been proposed. There are few phenomena in physics which have not in some way or other been impressed into pyrometric service, often indeed by methods of exquisite physical torture. I cannot, of course, even advert to many of these this afternoon, as my purpose will have to be restricted to such devices as have usefully survived. Thus a whole group of "intrinsic thermoscopes," as Lord Kelvin calls them—apparatus in which some property of the substance is singled out for measurement—will be overlooked. Pyrometry will some day receive substantial aid from the phenomena of solid thermal expansion, dear to the hearts of old Wedgwood, of Prof. Daniells, of the citizen Guyton-Morveau, and recently to Prof. Nichols, Dr. Joly and others; but even the "meldometer," which has received Ramsay's encouragement, and recent heroic attempts to measure the expansion of platinum, have not yet entered the arena to stay.² The same may be said of vapour pressure, ebullition and certain dissociations, of which the former is entirely too liberal in dispensing pressure, and the latter too negligent in readjusting it. Little has been done with heat conduction regarded as subservient to the measurement of high temperatures; little with colour and the spectrum, even though Draper and Langley in America, and many others elsewhere have paid tribute; little with polarisation. The wave-length of sound has told Cagniard Latour and our own A. M. Mayer much about high temperature, but it did not tell them enough.

Throughout the history of pyrometry, *fusion* seems to have come forward for journeyman duty. What is more convenient than to find whether the degree of red heat is too low or too high from the fusion of prepared alloys. As far back as 1828 Prinsep, aware of the golden opportunity, with his air thermometer, determined the melting point of some equally precious alloys of

¹ An address delivered by Prof. Carl Barus, before the Section of Physics, at the Detroit Meeting of the American Association for the Advancement of Science, August 1897.

² Noteworthy attempts to replace mercury by a liquid potassium-sodium alloy in glass thermometers are among the novelties.

gold, silver and platinum, and determined them very well. Other alloys were afterwards substituted, and graded mixtures made of quartz, chalk, kaolin and felspar for the purpose. Efforts to obtain more accurate values are due to Becquerel, but the absolute values most widely used until quite recently, namely, the melting points of silver (958°), gold (1035°), copper (1054°), palladium (1500°), platinum (1775°), iridium (1950°), are due to the researches of Violle.

Interest in high-temperature fusions has of recent date rather increased than abated. The demand for more accurate data has been met by the Reichsanstalt, and we have now a set of values for silver, copper, gold, nickel, palladium and platinum in terms of the air-thermometer standard of that institution. Data have also been supplied by Callendar. Among these values there is as yet considerable confusion, and the end is not yet. Long ago I suspected that the Violle melting points were probably too low, whereas the assumed zinc boiling point is probably too high. This surmise has been partially borne out by the Reichsanstalt, though Le Chatelier even now prefers Violle's values.¹

Thermoscopes based on a *specific heat* have an advantage over fusion thermoscopes in not being discontinuous. They are quite as "intrinsic" and much less convenient in practice. Guyton-Morveau at the beginning of the century pointed out the pyrometer importance of specific heat, and a host of observers followed him. But the critical discussion of the subject is due to Pouillet (1836), who determined the thermal capacity of platinum between 0° and 1200° absolutely, and found a value so nearly constant as to place this method of pyrometry in a very favourable light. Other observers followed with new data, and the bulk of our knowledge to-day is again due to Violle. Violle used Deville and Troost's exhaustion air thermometer, and determined the law of variations of specific heat and temperature throughout a large pyrometric interval with a number of metals, silver, gold, copper, palladium, platinum, iridium among them. It was by prolonging this law as far as fusion that the melting points of the metals, to which I have already alluded, were obtained. This verges on extrapolation, but it is not extrapolation gone mad.

The importance of calometric high temperature measurement has recently been accentuated in connection with the remarkable high temperature accomplishments of Moissan. Furnace temperatures in the case of such technological operations as are used in connection with iron, glass and porcelain manufacture, rarely exceed 1400°; except perhaps in the Bessemer process, where the temperatures are wont to exceed 1600° and even reach 2000°. In Moissan's furnace, which is essentially an electric arc enclosed by non-conducting lime, a totally new order of high temperatures is impressed. There was thus a call for at least an approximate measurement of their values which was answered by Violle, assuming that the specific heat of carbon above 1000° approaches a limit of 0.5 calorie. The sufficiency of this hypothesis is not unchallenged, however; for instance, Le Chatelier finds that, up to 1000°, the specific heat of carbon continually increases having no certain limit. Admitting Violle's results, Moissan's furnace temperatures exceed 2000° even at 30 amperes and 55 volts; at 360 amperes and 70 volts tin and zinc oxides melt and boil; they exceed 3000° at 500 amperes and 70 volts, where lime melts, and often boils. Moissan, however, went as far as 1000 amperes at 50 volts.

The striking novelty of Moissan's work is rather of chemical interest, and a large part of it is so fresh in our memory that in view of Moissan's valuable book ("Le Four électrique," par Henri Moissan; Paris, Steinheil), I need merely glance at it. A range of fusibilities, among which platinum lies lowest, while chromium, molybdenum, uranium, tungsten, vanadium, follow in order, and of ebullitions beginning with silica and zinc oxide, is rather breath-taking. Finally his structural investigations on the occurrence of carbon, and his long series of carbides, many of them commercially valuable, have staggered even the sensational press.

Leaving other intrinsic thermoscopes for the moment, I will ask your attention in this place to the development of the only fruitful method of absolute pyrometry which has yet been devised.

¹ The following table contains a brief summary:

Ag. (Violle)	954	(Barus)	986-985	(Callendar)	982	(H. & W.)	971
Au.	1045		1091-1093		1037		1072
Cu.	1054		1096-1097				1082
Ni.	—		1476-1517				1484
Pd.	1500		1585-1643				1587
Pt.	1775		1757-1855				1780

I refer, of course, to the gas thermometer, or, in other words, to the manometric methods of measuring the thermal expansion of gases. Efforts have indeed been made to use gaseous viscosity for absolute high temperature work. It has been definitely pointed out, inasmuch as viscosity in gases is independent of pressure, while both viscosity and volume increase with temperature, that the transpiration rates of gases through capillary tubes of platinum glazed externally would necessarily be an exceedingly sensitive criterion of the variation of high temperatures. The small volume of the transpiration pyrometer as compared with the clumsy fragile bulb and appurtenances of the air thermometer is further to the point. But modern kinetics has as yet failed to fathom the law of variation of viscosity with temperature, and even the researches of O. E. Meyer in this direction do not seem to have quite touched bottom. Gaseous transpiration pyrometry is thus still much in the air, surveying the horizon of a glorious future.

Returning from this digression to the air thermometer, we find the first thorough-going piece of high temperature work carried out by Prins (1829) by the aid of a reservoir of pure gold, to which I have already alluded. Prins's manometer was filled with olive oil, and the volume issuing at constant pressures was found by the balance. In view of the pure olive oil, probably available in 1829, these experiments must have been comfortably appetising, and I dare say Prins's good humour in the matter may have contributed to the remarkable excellence of his results. Prins's researches were not superseded until Pouillet, in 1836, published his paper on pyrometry. Pouillet constructed an air-thermometer bulb of platinum, and was thus able to reach the farthest pyrometric north of the day and long after. His results are many-sided; they contain the first definite data in radiation pyrometry and in calometric pyrometry. His constant pressure manometer, afterwards further perfected by Regnault, is the best apparatus for the purpose to-day. Pouillet did not suspect, indeed he remained quite unaware of, the permeability of platinum to furnace gases; perhaps for this and other reasons he failed to detect the thermo-electric anomalies in the platinum-iron couple which he has so carefully calibrated.

It was thus a great step in advance when Deville and Troost long after replaced platinum by glazed porcelain, availing themselves (1857-60) of Dumas' famous vapour density method for measuring temperature. Unfortunately for the rapid progress of pyrometry Deville and Troost used iodine vapour in their bulbs, a heavy gas indeed, but a gas, as was afterwards found, whose low temperature molecule dissociates at higher temperatures. Thus they unwittingly committed an even greater error than Pouillet in gliding over permeable platinum; and their data for the boiling points of zinc and of cadmium were about 100° too high. In fact these results were challenged not long after by Becquerel (1863), who had fallen heir to Pouillet's platinum air thermometer, had used it to calibrate a platinum-palladium thermo-couple of his own, and had found data for the boiling points of zinc and cadmium upwards of 110° below those of Deville and Troost. I cannot here enter upon the discussion which thereafter arose between these active observers, further than to state that in the course of it both parties frequently repeated their measurements (Becquerel even substituting a porcelain bulb for Pouillet's thermometer) without removing the discrepancy between their values.

Later researches have decided in favour of Becquerel's results, and his original research, with its applications to fusion, to radiation, to thermo-electrics, &c., is one of the noteworthy accomplishments in the history of pyrometry. Nevertheless it must not be forgotten that to the investigation of Deville and Troost our knowledge of the perviousness of iron, platinum, and other metals to gases is due. We are also indebted to Deville for the great discovery of dissociation, the very phenomenon which he was here so loth to acknowledge. This is the case of a man stumbling in his own footprints. Victor Meyer was, I believe, the first to point out the probable dissociability of the iodine molecule, suggesting a fruitful subject of research which has since been extended to many other molecules.

In 1863, Deville and Troost began a new series of high temperature researches, the feature of which is the perfected form of porcelain bulb. This was a hollow sphere and long capillary stem adapted for use with Regnault's standard air thermometer. Great difficulties were encountered in the endeavour to glaze the bulbs within. They were finally overcome by making bulb and stem separately, and then soldering them together with felspar before the oxyhydrogen blow-pipe. Elaborate measurements

on the thermal expansion of Bayeux porcelain accompanied these researches which, undertaken together with M. Gosse of the Bayeux works, occupied them intermittently for about seven years. A full summary of their data did not appear, however, until 1880, when, together with a new vacuum method of high temperature air thermometry, they communicated the results of twenty-seven measurements on the boiling point of zinc. Their new results are in good accord with the data of Becquerel, already cited, and the more recent results of Violle and others for the same landmark in the region of high temperatures. Measurements between 0° and 1500° had thus reached a degree of precision of about 15° in 1000° .

The further development of pyrometry took a somewhat different direction. Regnault (1861) had already made use of a displacement method, in which the measuring gas is removed bodily into the measuring apparatus by an absorbable gas. But the method was independently revived by Prof. Crafts, of the Boston Institute of Technology. These methods are not of especial excellence below 1500° ; but above that temperature, when most solids tend to become viscous, their importance increases (as Crafts duly pointed out) in proportion to the rapidity with which the measuring operations can be completed. One or two minutes may suffice, and different gases may be tested consecutively. It is in this way that Victor Meyer and his pupils, after demonstrating the dissociation of iodine and chlorine molecules, succeeded in penetrating quantitatively to very much less accessible heights of temperature. A particular desideratum was a rigid test as to the stability of the molecule of the standard measuring gases (oxygen, hydrogen, nitrogen). The results were favourable inasmuch as for these and for many gases, like CO_2 , SO_2 , HCl , Hg , &c., the expansions obtained were linear functions of each other.

In their final work, temperatures as high as 1700° were reached, the air thermometer for this purpose being tubular in form, consisting of very refractory fire-clay with an interior and exterior lining of platinum and with two end tubulures of platinum for influx and efflux of gases. Among many results of great chemical interest their researches showed that metallic vapours, phosphorus, sulphur, &c., at high temperatures tend to pass into the monatomic or the diatomic molecular structure.

Some time after (1887) a series of experiments furthering the line of research of Deville and Troost were made with a geologic aim in view in the laboratory of the U.S. Geological Survey. Finally, porcelain air thermometry was taken up with great vigour by the Reichsanstalt. These results, due to Holborn and Wien, are now almost exclusively quoted, and carry the stamp of the great institution from which they emanated. They have been wisely made commercially available by the deposition with Heraeus in Hanau (Germany) of a platinum rhodium alloy definitely calibrated for a temperature range of 1400° .

Apart from this, these researches contain no essential novelty except, perhaps, a more detailed attempt to investigate the stem error of the thermometer bulb; their procedure otherwise is identical with the method developed in America. I am not therefore inclined to yield to it the unhesitating deference which has become customary. There can be no doubt, in view of the splendid facilities due to the co-operation of the Royal Prussian Porcelain works—facilities which those who have been baffled by porcelain technology, or have had to coax unwilling manufacturers into reluctant compliance, will appreciate—that the data of the Reichsanstalt will eventually be standard. For the present, however, I should be more impressed by some sterling novelty either in the direction of a larger range of measurement, or of method. Conceding that an accuracy of 5° at 1000° has been reached, all results above 1500° remain none the less subject to increasingly hazardous surmise.

A beautiful method of absolute thermometry, albeit as yet only partially developed, is due to Töpler. In this the densities of communicating columns of gas are compared very much as in Dulong and Arago's classical method for liquids, by the gravitation pressures which correspond to these unequally hot columns. To accomplish such extremely fine-pressure measurement, Töpler invented the "Druck libelle," an inversion, as it were, of the common level, in which therefore the motion of the bubble (or of a thread of liquid) indicates a change of pressure conditioned by the invariable horizontality of the instrument.

The development of the practical forms of continuous intrinsic thermoscopes (the radiation, the thermo-electric, and the electric resistance methods) went more or less hand in hand with the

development of the air thermometer, although the latter is decidedly the more recent. Aside from pioneering experiments of Müller (1858) and others, the well-known Siemens resistance pyrometer (1871) was the first instrument in the field. It was based upon data obtained from platinum, copper and iron, by the calorimetric method of calibration. This instrument has been remarkably perfected by Callendar and Griffiths, using specially pure platinum calibrated by comparison with the air thermometer as far as about 600° . Notwithstanding these improvements the resistance pyrometer is inferior in my judgment to the thermo-electric pyrometer on account of the greater bulk and fragility of the exposed parts, and the tendency of platinum to waste itself gradually at high temperatures. Its upper limit of temperature measurement is thus limited; for even if the difficulty of selecting suitable terminals for the coil is set aside, the difficulty of finding an insulator at very high temperatures would remain. According to Holborn and Wien resistance is seriously subject to the influence of furnace gases, and permanence of the low temperature constants does not imply a like permanence of the high temperature constants of the metal.

Radiation pyrometry, curiously enough, is the most venerable method within the whole scope of the subject. It was introduced by Newton (1701) in his *scala graduum caloris*, in connection with his well-known law of cooling. Not to mention minor workers, it was successfully attacked and revived in most of the noteworthy high temperature investigations. Pouillet and Draper have studied it; Becquerel, Crova, Violle, Le Chatelier, Langley, Nichols, Paschen and others have advanced it. It remains to-day the most promising, as well as puzzlingly fascinating, subject for pyrometric research. One need merely advert to its broad scope in relation to the temperature of the heavenly bodies to acknowledge this. Here I can only allude to Becquerel's principle that the radiation of opaque bodies is spectrometrically alike at the same temperature, a result which has Crova's more recent assent; to Violle's photometric measurements of the total emission of platinum; to the more recent work in the same direction of Violle and Le Chatelier, in which consistent results were obtained for oxide of iron and platinum as far as 1500° to 1700° ; to Stefan's law, as proved by Boltzmann and the variety of discussion it has elicited; to H. F. Weber's collateral equation; to the Johns Hopkins measurements, &c. Another school of observers, including Langley, Paschen, and others, has undertaken the promising but much more laborious method of bolometric measurement of the distribution of spectrum energy in its relation to temperature. Without doubt, however, the whole subject is yet *in primis rudimentis*; the results are confessedly "intrinsic." Indeed, vagueness in the nature of the radiating source lowers with sufficiently threatening aspect to chill the fondest hopes. When one is told by Violle, working on Mont Blanc, that the temperature of the sun is 2500° ; thereupon by Rossetti that it is 9965° , by Le Chatelier that it is at least 7600° , by Paschen that it is below 5000° , by Wilson and Gray that it is 8000° , &c., one wisely concludes that more may yet be learned about it. Our sympathies naturally go with those who, like Lummer and Wien and the Johns Hopkins people, are beginning fundamentally with the search for an absolutely black body. Less superstructure and more sub-cellular is perhaps the watchword in radiation pyrometry.

Turning now to the last and most important of the methods of practical pyrometry, we find a curiously meandering evolution apparent. I have already indicated that Pouillet (1836) was the first to complete a legitimate piece of calibration work. Pouillet might have condemned the method, but for some reason Tait's thermo-electric anomalies of red-hot iron were not detected. Regnault (1847), who was the next to take up the subject as it happened with the same couple, made this condemnation sweeping enough. It was not the real perversity of the platinum-iron couple which provoked Regnault, for of this neither he nor Pouillet became aware. Regnault's objection (as we should put it to-day) lay in the fact that the thermo-couple obeyed Ohm's law, which in that early day lay somewhat beyond the great physicist's range of interest. Fortunately, but none the less long after, Becquerel followed with his palladium and divers platinum couples, carefully calibrated and efficiently used. What these platinum couples were is not stated. They cannot have been very sensitive, or they would have been preferred to the palladium-platinum couple. Indeed, the metallurgy of platinum alloys did not reach a degree of refinement until Deville and Debray (1875) overhauled the chemical separation of platinum

metals with particular reference both to iridium and to rhodium. Recently Mylius and Förster at the Reichsanstalt further contributed to platinum metallurgy. But in view of the toils in which the whole subject of high temperature measurement languished in Becquerel's day, his results were not sufficient to remove the discredit which Regnault had thrown upon thermo-electric pyrometry. And so it happened that the return to the method in recent date was of the nature of a resuscitation.

It is amusing to note, as we pass on, the pranks of custom as it bore down upon pyrometry. Following Deville and Troost, every worker (I might mention at least five) felt in duty bound to redetermine the boiling point of zinc—rather a difficult feat in its way. Thus we find boiling zinc inseparably associated with the destiny of the calibrated thermo-couple. Le Chatelier broke this law of fateful sequence by ignoring the need of calibration at the outset, and then using the couple so dignified to determine the melting points of silver, gold, palladium and platinum. But these are Violle's melting points. Hence the pyrometric feature of Le Chatelier's platinum-rhodium couple was in its inception due to Violle.

Meanwhile, accompanying the geologic inquiries of Clarence King, an extensive series of pyrometric investigations which had been in progress in the United States since 1882 were completed (1887). These contained a full examination of divers efficient methods of pyrometry and a study of the porcelain air-thermometer with particular reference to the calibration of thermo-couples. In the course of this work the admirable pyrometric qualities of the platinum-iridium alloy were exhibited by detailed and direct comparisons with the air thermometer. It was shown that the calibration could be made permanent by referring the thermo-electromotive forces to a Clark's cell; that the character of their variation with temperature is uniformly regular, and that the thermal sensitiveness of the couples increases as the higher degrees of red and white heat are approached. Finally it was pointed out that couples destroyed by silicate corrosion, or in similar ways, could be restored by fusing over again on the lime hearth with merely negligible changes of constants. Elsewhere, Le Chatelier's clever combination of the platinum-rhodium couple with the D'Arsonval galvanometer, then a comparatively new instrument in the laboratory, secured immediate favour. Prof. Roberts-Austen, ever on the watch to waft good things across the channel from Gaul into Albion, hailed the new-comer with no uncertain sound. Some time after, the platinum-rhodium couple entered Germany, and was there definitely calibrated (1892) for the first time, as already stated, at the Reichsanstalt.

Of the three available couples, palladium, platinum-rhodium and platinum-iridium, the former is excluded from competition by reason of its low fusibility. Between platinum-iridium and platinum-rhodium, the latter has been more extensively advertised but is otherwise inferior to the older platinum-iridium alloy. In other words, platinum-iridium, when suitably alloyed, can be made more sensitive than platinum-rhodium in the ratio 100 to 76. Beyond this the alloys are much alike; both are tenacious, resilient, refractory metals, and their thermo-electric forces under like conditions of temperature show a constant ratio even at extreme white heats. The thermo-electric activity of these two alloys is exceedingly remarkable. Among over fifty different platinum alloys examined no similarly sensitive combinations were found. Moreover, whereas platinum alloys of extremely large electrical resistance are not unusual, such metals are not to be distinguished thermo-electrically.

To conclude: the small dimensions of the sensitive point of the thermo-couple, the independence of the intermediate temperatures between the junctions (apart from small corrections due to the Thomson effect), and therefore the removal of the terminal difficulty, the high upper limit of the measurable temperatures, the permanence of its constants in relation to Clark's cell in the lapse of time, the instantaneity of its indications, the easy reproduction of destroyed couples, their relative insensitiveness to furnace gases, the regular and simple character of the temperature function, the sustained sensitiveness throughout all temperature ranges even quite into the fusion of platinum—all these facts are a sufficient if not an overwhelming recommendation of the method.

In speaking of long range temperature variables, one is hardly permitted to overlook the remarkable work which has recently been done in the direction of low temperature; but with these subjects I am less familiar, and can therefore only refer to in passing. The progress made in the subject is sufficiently evidenced by the growth of large low temperature laboratories

throughout the world, laboratories which undertake "the cold storage" of "cold storage," as it were, like those of Pictet in Berlin and Paris, of Dewar in London, of Kamerlingh Onnes in Leyden, of Olszewski in Krakau, and others. Dewar and Fleming have added to our knowledge of the probable constitution of bodies at the absolute temperature. Olszewski has found the critical temperature of hydrogen 'at -230° and its atmospheric boiling point at -243° . Dewar and Moissan have liquefied fluorine. There is much here which I must reluctantly forego. The hydrogen thermometer, the platinum balance (Callendar), and the thermo-couple are again doing excellent work in thermometry.

APPLICATIONS OF PYROMETRY.

Turning now to the applications of recent pyrometry, we meet first many series of valuable data on melting points and similarly valuable data on the dissociation temperatures of chemical compounds. To these I merely refer, not being qualified to enter into chemical interpretations. High temperature boiling points have also been treated, and I will especially consider the case of the variation of metallic ebullition with pressure. The relation of vapour pressure to temperature has thus far defied the counsels of the wise, even though such men as Bertrand and Dupré have given the matter close scrutiny. One would suspect the simplest relation to hold for metallic boiling points, and investigations have therefore been undertaken in which the temperature of ebullition of Hg, Cd, Zn, Bi, were studied for pressures decreasing from one atmosphere down indefinitely.

The results so obtained show an effect of pressure regularly more marked as the normal boiling point is higher, so that the attempt to express the phenomenon for all these bodies by a common equation is roughly successful. By far the most rapid reduction of boiling point occurs when the pressure decreases from $\frac{1}{10}$ atmosphere indefinitely. For the case in which the normal boiling point is to be predicted from a low pressure value in case of a metal which, like bismuth, boils with great difficulty, very high exhaustion is essential.

Igneous fusion, by which I mean the fusion of rock-forming magmas, is particularly interesting in its relation to pressure. This has been again recently pointed out by Clarence King in his discussion of the age of the earth. If the earth is solid within, as is now generally admitted, such solidity can only result from superincumbent pressure withholding fusion. To study the relation of melting point to pressure directly is out of the question when white heat is the condition of fusion. In this respect the laboratory in the interior of the sun or even of the planets has some salient advantages; but we cannot comfortably put such a laboratory under strict surveillance of protoplasm.

Fortunately the Clapeyron equation, successively improved by James Thomson and by Clausius, is here usefully available. To measure the melting point, the difference of specific volumes of the solid and the liquid body and the latent heat of fusion at this temperature, with the aid of Joule's equivalent, is to measure also the relation of melting point to pressure implicitly. Based on the first and second laws of thermodynamics, this equation is generally true, no matter what specific properties may characterise the body. The process has thus far been completely pushed through for diabase only. Thermal change of volume may be measured by enclosing the rock in a platinum tube of known expansion, and the contraction of the contents from liquid to solid found by an electric micrometer probe reaching within the tube. Given a furnace fully under control, then, as experiment has shown, the cooling can be made to take place so slowly that platinum remains rigid relatively to its charge of red-hot magma, and under these conditions the contraction can actually be followed into the solid state. At the same time, the temperature at which marked change of volume occurs is the melting point. Apart from difficulties of manipulation, the latent heat may be found from measurement of thermal capacity on either side of the temperature of fusion, by a modification of known methods.

The rate at which fusion is retarded by pressure, computed from these data in the manner specified, showed an increase of the melting-point of a silicate of about 0.025° C. per superincumbent atmosphere. But this datum falls within the margin ($0.02 \dots 0.04$) of corresponding data much more easily and directly derived for organic bodies. One may therefore argue that if the melting-point pressure rate is so nearly constant on passing from the class of siliceous to the thoroughly different and

much more compressible class of organic bodies, the rate would probably be more nearly constant in the same body (siliceous or organic) changed only as to temperature and pressure. This surmise was verified for naphthalene within an interval of 2000 atmospheres.

The endeavour to interpret the change during fusion of the volume of the chemical elements in terms of the periodic system has been begun with much success by Max Töpler for low temperatures. It would be of great interest to complete this diagram for high temperatures in view of the specifically molecular character of the fusion phenomenon, by repeating such experiments as have just been described for rock magmas.

The heat conduction of rocks has been investigated in many cases for temperatures lying below red heat. Among recent observers we need only instance the extensive investigations of Ayrton and Perry. No trustworthy experiments, however, have yet been carried into the region of essentially high temperature; and yet, what is chiefly of interest in the geological applications of such experiments is the change of conduction which accompanies changes of physical state, whether induced by pressure or by temperature.

Experiments in heat conduction are difficult under any circumstances. They become insuperably so when conduction at white heat is to be studied under pressure, and that is what the geological conditions actually imply. Some notion of a body respectively solid and liquid at a given temperature may be obtained by observing the behaviour of bodies which are capable of being under-cooled. A number of such bodies are known, thymol being a conspicuous example. Experiments with this body were made by measuring the volume expansion, specific heat, and heat conduction in parallel series both for the solid and liquid state at like temperatures. They showed, for instance, that the increment of absolute heat conduction, encountered in passing isothermally from the solid to the liquid state, when referred to solid conductivity is about 13 per cent., and when referred to a liquid conductivity is about 15 per cent. Similarly, the change of thermometric conductivity, under like conditions, is an increment of 36 per cent. and 56 per cent. respectively. Now, since in most questions relating to thermal flow thermometric conduction enters exclusively, the importance of this large coefficient is obvious whenever a body passes from the solid to the liquid state.

Solid conduction is thus 40 or 50 per cent. in excess of liquid conductivity for the same body at the same temperature and pressure. It is reasonable to infer that a corresponding decrement of conduction will accompany any rise of temperature of a solid body. Measurements which have somewhat recently been made for relatively small intervals at Zürich, at Glasgow, and at Harvard upon typical rocks, all bear out this surmise. The immediate incentive to these experiments was a strong paper by Prof. Perry, in which Lord Kelvin's estimate of the age of the earth is shown to be insufficient for an earth in which the interior conductivity is systematically greater than the surface conductivity. Indeed, he deduces the percentage increment of the square root of the age of a Perry earth over that of a Kelvin earth to be one-fifth of the percentage decrement of conduction for each 100°C . So far as the effect of terrestrial temperature alone is concerned, the measurements just mentioned show that Perry's correction is negative or that Perry's earth would be less long-lived than the 100×10^6 limit of years set by Lord Kelvin.¹

To estimate the effect on heat conduction of the increase of pressure which accompanies the increase of temperature with the depth below the surface is a much more serious matter. In the laboratory, pressure experiments are limited to 3000 or 4000 atmospheres; compared with earth pressures, these scarcely amount to a scratch on the surface; yet even for this limit the determination of heat conduction at high temperatures is out of the question. A tentative method of arriving at a conclusion is given by Clarence King in his discussion of the age of the earth, the consequences of which have been quite overlooked. What King endeavoured to accentuate, long before Perry's contribution to the subject, was precisely the fact we cannot assume greater conductivity for the interior than for the surface. Since heat conduction decreases isothermally from solid to liquid, it was assumed that, in one and the same substance, the viscosity could be taken as an index of the thermal conduction. Therefore if tempera-

ture and pressure were made to vary in such a way (both increasing) as to leave viscosity constant, it was inferred that heat conduction would also remain constant. Now the isometrics or lines of constant viscosity of a viscous body for variable pressure and temperature are much more easily found than the isometrics of conduction. In fact, it has been shown that a burden of at least 200 atmospheres would have to be brought to bear in order to wipe out the decreased viscosity due to the rise of a single degree (Centigrade) of temperature. The depth at which this ratio is reached, as King points out, for a given surface gradient of temperature and depth, depends on the initial excess of the temperature of the earth considered, and on the age of the temperature distribution resulting. But no matter whether the Kelvin earth with an initial excess of 3900 and an age of 100×10^6 years, or whether King's solid earth with an initial temperature of fused platinum and 25×10^6 years of life, be taken—in all cases the temperature effect predominates throughout those depths within which change of temperature with depth is the marked feature of the temperature distribution. In other words, if, for example, we consider the Kelvin earth, the strata above 0.035 of earth radius will be strata of smaller conduction than the surface strata. From the surface downwards as far as 0.035 radius, conduction will decrease to a minimum. Below this, conduction will increase again due to preponderating pressure, finally to exceed the surface value. But the computed temperature distribution of Kelvin's earth is such that at 0.035 radius the initial temperature excess of 3900° has been reached to within 1 or 2 per cent. Below this in depth, Perry's correction would begin to apply, but the further changes of temperature are so nearly negligible that the consideration of conduction is superfluous. From this point of view, therefore, the staggering force of Perry's clever argument is removed. Of course, I am fully aware that an argument from the supposed parallelism of physical properties of a given body (in the present case heat conduction and viscosity) is not inevitably convincing; but in physical geology, for some time to come I dare say, the question will be not one of rigorous proof, but rather one of forming a rational opinion.

In passing I will indicate the importance of an increased knowledge of the isometrics of liquid and solid matter, relations which have thus far been found simpler in character than other thermodynamic properties, as I shall again point out in the course of the address.

I want, finally, to add a few words on the electro-chemistry of magmas. The physical chemistry of molten rock has already been somewhat extensively considered, but I am hardly competent to review it. In the United States, Joseph Iddings and, more recently, George F. Becker have discussed the natural differentiation of magmas from different points of view. Here I will merely include certain pyrometric experiments on the electric conduction of fused glasses which seem to give promise of throwing light on the chemical constitution of complex silicates and to be suggestive in other ways. In such measurements, if the magma is made to pass from the solid to the liquid state, the observed electric conduction contains no evidence either of a melting point or of polymerism. The law of thermal variation is easily derived and it agrees closely with the corresponding behaviour of a zinc sulphate solution, for instance, observed through a range of temperature. In a general way, electric resistance decreases in geometric progression when temperature increases in arithmetical progression. Considered relatively to the composition of the magmas, electric conduction shows a marked and regular increase with the degree of acidity of the magmas. The less fusible acid magmas are better conductors than the basic magmas at the same temperature. Curiously enough, conduction thus runs in an opposite direction to fusibility. However viscous a magma may be, therefore, and however cogent the arguments such as those launched by Becker against the differentiating importance of ordinary diffusion may prove, it is fair to conclude that a thorough change of chemical structure through ionic diffusion, whether directed by an electric field or otherwise, must be an easy possibility for a sufficiently hot, but otherwise solid, magma. The results point specifically to the desirability of repeating Hittorf's brilliant experiments on the migration of the ions for a siliceous medium. This ought not to be difficult, seeing that such a menstruum need not even be liquid to be compatible with a high order of electric conduction.

Further consideration of the subject shows the probable passage of conduction through a maximum when acidity is con-

¹ The text of Kelvin's recent address at the Victoria Institute, in which an age of thirty million years is maintained, has not yet reached me.

tinually increased. Finally, quartz appears like an insulator in the same rôle as water in ordinary aqueous solutions. In all these cases I wish to keep in mind the results of Alexéeff and their recent repetition for metallic alloys, together with the interpretation of these results due to Masson. In a crust subject to variable magnetism, traversed by earth currents, sustained by semi-metallic carbides of the Mendeleeff-Moissan type, containing piezo-electric and thermo-electric sources, who can say that electric fields are absent? Again, the character of the changes contemplated in Gibbs's famous "phase rule," as interpreted by Le Chatelier, would here be ionic rather than molecular.

A question of somewhat allied interest is the action of hot water under pressure on rock-forming silicates. Investigations of this kind have been described in the well-known and fascinating book of Daubrée. Daubrée's work, however, is qualitative in character, like that of many others in the same line, and the furtherance of the subject is to be looked for in the quantitative direction. Some time ago, Becker suggested experiments on a huge mass of granulated rock under the action of steam at exceptionally constant temperature. But no thermal effect of the action of water could be detected. True, the boiling point of water is a temperature relatively low for the purpose; yet similar experiments made with liquid water at over 200° under pressure were equally negative as to results. Experiments of this kind are not very conclusive. The insufficient sensitiveness of the measuring apparatus, the rate at which heat is carried off compared with the rate of generation, and other obscure causes mar the results. The question may, however, be approached in a somewhat different way: if water is heated under pressure in glass tubes, the volume of water contained decreases as the square, whereas the chemically active area, *i.e.* the inside surface of the tube, decreases as the first power of the diameter. Hence, in proportion as the tube is more capillary, the action of water on the glass will produce accentuated volume effects. Thus it was shown that the behaviour of hot water is profoundly modified by its continued action on glass, inasmuch as its compressibility increases at a very rapid rate with the time of action even at 180°, until, with the approach of solidification, the observed compressibility is fully three times its isothermal value at the inception of the experiment. Even more striking is the simultaneous and continual decrease of the length of the column of water. Clearly, therefore, the confined volumes of glass and included water must undergo contraction at 180° in forming an eventually solid aqueous silicate, while increasing compressibility is due to the increasing quantity of silicate dissolved. Now, in nearly all cases the effect of solution is a decrease of compressibility. Hence the increased compressibility observed is to be referred to a precipitation of the dissolved silicate, in response to the action of pressure, a result borne out by the appearance of the tube and by varied correlative experiments. It is, however, the volume contraction which is particularly interesting, because of its far-reaching geological application. In the first place, the measurements show that about '025 cubic cm. of liquid water is absorbed per square centimetre of glass surface at 180° C. per hour.¹ The effect of this absorption is a contraction of bulk amounting to 18 per cent. per hour. So large and rapid a contraction is presumably accompanied by the evolution of heat. Hence, under conditions given within the first five miles of the earth's crust, *i.e.* if water at a temperature above 200° and under sufficient pressure to keep it liquid be so circumstanced that the heat produced cannot easily escape, the arrangement in question is virtually a furnace whose efficiency accelerates with rise of temperature or increase of terrestrial depth.

PIEZOMETRY.

It is not feasible to make much progress in pyrometry without feeling the need of a corresponding development in high pressure measurement. This has already appeared in the preceding parts of my address. It will not be expedient to look into the history of the subject so comprehensively as I did in the case of pyrometry, partly because the literature is more diffuse, and partly because the real development of piezometry is of recent date and virtually begins with pressures of the order of several thousand atmospheres. So understood, although we gladly pay homage to Oersted, to Regnault, to Grassi and many others, our historical summary may be abridged.

As is often the case in physics, the great advances in the

subject are associated with the name of one man; for though many able investigators have contributed effectively to the progress of piezometry, the overshadowing importance of the results of Amagat have superseded all researches coextensive with his own. For over twenty years Amagat has been labouring on this definitely circumscribed subject. Year after year his prolific experimental ingenuity has put forth results, each of which in its turn constituted the highest attainment in accuracy and the greatest breadth of scope which high-pressure measurement had reached at the time. It is impossible to give any adequate view of this sustained labour in an address. The subject is highly specialised and demands special treatment; but we owe to Amagat the bulk of our knowledge of the properties of a gas regarded not as an ideal fluid, but as a physical body; some of the most far-reaching results in the thermodynamics of liquids and some of the best data in the elastics of solids.

Amagat investigated gases within an interval of pressure which at times reached 4000 atmospheres, with a view to interpreting their divergence from the laws of ideal gaseity. Indeed we may note in passing that, just as the advanced astronomy of the day is being enriched with unexpected discoveries from a discussion of mere errors of observation, so refined physical measurement gleans new harvests in carefully tracing out the all but rigorous sufficiency of established laws. The product of pressure and volume, nearly constant in the ordinary isothermal behaviour of gas, shows, under higher pressures, a well-marked passage through a minimum in the case of all gases except hydrogen. Hence below a certain definite pressure, varying with the character of the body (say 40 atm.), gases are more compressible than Boyle's law asserts, and above this pressure they are continually less compressible and begin to resemble hydrogen in this respect. The sharpness of the minimum diminishes as temperature increases and probably ultimately vanishes. Cailliet, it is true, had undertaken a study of the same subject simultaneously, but his results were not in the same degree correct. Again, the coefficient of expansion of gases considered in its isopiestic behaviour for temperatures not too far above the critical point, increases with pressure to a maximum, which seems to occur at the same pressure for which the volume-pressure product is a minimum. This thermal maximum also decreases with temperature and finally vanishes. To specify the conditions further than this would be to exceed the limits beyond which verbal statement ceases to be lucid. The value of Amagat's work, however, is not merely the formulation of such general laws for gases as a whole, but rather the investigation of sharp and specific results for each gas individually. Thus if one uses these data for a given gas to compute the constants in Van der Waal's law, one is actually able to predict remote critical conditions of the gas in question with a fair degree of accuracy.

Whenever pressure measurements are to be made through such large intervals as are here in question, the elastic constants of the apparatus become of increasing moment. Amagat, however, treated these incidental measurements as of like importance with the rest of his labours. The starting point of his investigation into high pressures was the open mercury manometer first erected along a staircase near Lyons, finally in the shaft of the St. Etienne Mine, about 380 metres deep. This apparatus was used for graduating the closed manometer, preferably containing nitrogen. In later experiments for excessively high pressures, the closed manometer was replaced by the "manomètre à pistons libres," a sort of inverted Bramah press, in which the small pressures of an open mercury manometer acting on a large piston compensate the relatively large pressures of the piezometer acting on a small piston. The ingenious feature of Amagat's apparatus is the rotation of both pistons just before measurement, a device by which friction is rendered harmless. Equipped with this instrument, direct determination of the bulk modulus for glass and metals was actually feasible. In the case of glass no serious variation of the compressibility could be ascertained within 2000 atmospheres and even 200°, an observation of great value in practical research. Poisson's ratio was similarly determined, and the data used in computing Young's modulus. But the most important result of these researches, a result to which Prof. Tait also contributed, is the datum found for the absolute compressibility of mercury. This will enable all future observers in piezometry to standardise their apparatus with ease and nicety.

Time prevents me from dwelling upon the remaining investi-

¹ This is an initial rate of about 180 kilograms per square metre per year.

gations of Amagat in a measure commensurate with their value. These contain a counterpart for the liquid state of the results already announced for gases. The change of volume throughout enormous pressures and about 200° of temperature is considered in detail for a number of important liquids. Only in one case, and that the rather remarkable one of carbon tetrachloride, are evidences of solidification encountered, and the conditions determined. Amagat believes the absence of solidification to be due to the occurrence of the lower critical temperature below the isothermal of compression. In my own judgment, however, the pressures necessary to reach this lower critical point will be enormous even in units of 1000 atmospheres, for which reason it is not in any case liable to be an easy conquest.

Special mention, finally, is due to the thermal position of the maximum density of water, which Tait had already studied. Amagat shows definitely that the temperature of maximum density moves towards the freezing point with increasing pressure, so that at high pressures, as well as at high temperatures, the behaviour of water loses its anomalous character. In general, compressibility and expansion decrease with pressure for all normal liquids, and expansion increases rapidly with temperature. Other anomalous properties of water have been investigated, among which the diminished viscosity of water under pressure at ordinary temperature, studied by Röntgen, Cohen and others, may be stated.

After this cursory and wholly inadequate mention of the work of Amagat and the physicists who, like Tait, Cailliet and others, have been engaged in closely allied researches, it will repay us to look at some of the other as yet less splendidly developed contributions to piezometry. At the outset it is well to make mention of the forms of pressure gauges which have come into use. As far as 1000 atmospheres, the Bourdon gauge, if well constructed, does good service, though in a somewhat rough way. The corrected nitrogen closed manometer is more accurate for a smaller range. A theoretically simpler pressure gauge was proposed by Tait and Cailliet. In this case a straight cylindrical elastic tube under internal or external pressure is substituted for the Bourdon tube, and the expansion or compression is directly measured. With due precautions against changes of temperature and the choice of a solid of constant bulk modulus and rigidity, this gauge can be used as far as about 2000 atmospheres with convenience.

Above 2000 atmospheres, Amagat's Bramah press manometer, already mentioned, is the only trustworthy gauge, and though somewhat cumbersome has the advantage of giving absolute results. However, a gauge based on the change of electric resistance of mercury with pressure, a constant now fairly well known from Palmer's measurements, will in my judgment do good service for pressures which exceed even the range of the manometer. With regard to methods for producing high pressures, the force pump, with a small steel plunger and the screw advancing bodily into a closed barrel filled with a liquid, have not yet been superseded. The efficiency of such apparatus depends essentially on the means used for obviating leakage. These must, of course, be very perfect.

Amagat's work with liquids was extended chiefly in the direction of high pressures. Experiments have since been made by others throughout higher temperatures (310°), and of course a smaller range of pressures (500 atm.). Leaving out the less perspicuous results, I will here merely allude to the probable existence of a remarkable law which these researches have developed. Dupré (1869) and afterwards Lévy (1878), reasoning from thermodynamic premises, were the first to suspect that the isometrics or lines of equal volume of liquids are straight. In other words, if there is to be no change of volume, then pressure increments must vary proportionately to the temperature increments ($p = a\theta - b$), a result which implies that the internal pressure of a body kept at constant volume is proportional to its temperature. Lévy's deduction was, however, declared to be theoretically unwarrantable by Clausius, Boltzmann and others. Some time after, the same law reappeared in experimental form in a series of brilliant researches on critical temperatures due to Ramsay and Young. Fitzgerald, reasoning from Ramsay and Young's results, then proved that for such liquids as possessed straight isometrics, specific heat is a temperature function only, and energy and entropy are each expressible as the sum of a mere temperature function and a mere volume function. This is curiously like the position from which Dupré and Lévy started. Ramsay and Young's work, however, applied specifically to vapours, and for

high temperatures (200°) their pressures did not exceed 60 atmospheres. The law has since been tested for liquids as far as 1500 atmospheres and over 200° conjointly, and found in reasonable accordance with experiment. Hence we infer that if the thermodynamic change of a body is such that volume remains constant, pressure and temperature will vary linearly with each other, the increments being about 0.1° C. per atmosphere. Now, although any law relating to the liquid state would be welcome, these volume isometrics are particularly so. In the geology of the earth's crust, for instance, they would in a great measure determine the conditions of possible convection; and it is curious to note that from the known values of bulk modulus and of the expansion of solid glass, the isometrics would here again be given by corresponding increments of about 0.1° per atmosphere. For solid metals the isometrics are of a different order.

Another line of research for liquids to which I attach supreme importance has only just been begun: I refer to the systematic study of the *entropy* of liquids. Among the first results on the heat produced in suddenly compressing a liquid are those of Tait. They are of too limited a range, however, and not in good accord with the more recent and extended data of Galopin. Generally speaking, the change of temperature produced per atmosphere of compression increases with temperature in a marked degree, as one may infer from Kelvin's equation. For organic bodies this increment at ordinary temperatures is of the order of $\frac{1}{2}^\circ = .020^\circ$ per atmosphere. In case of liquid metals the order of values is decidedly different, being about $\frac{1}{10}$ this value, recalling correspondingly divergent results observed for the isometrics of volume. Quite recently (1896) the same subject has been taken up by Tammann (to whom we also owe results for the correlative compressibility), particularly for solutions and with reference to the theory of solutions. Tammann's data are of the order 0.001° per atmosphere at 0°, and in better keeping with the thermodynamics of the subject than the earlier experiments. Much more, however, must be done before anything like a degree of critical accuracy is approached or a broad survey taken. Pressure intervals are to be chosen wider, and the temperature measurement given with greater certainty.

Finally, I wish to touch upon the relations of melting-point and pressure in their more recent development. Obviously the classical work of Andrews on the continuous passage of a liquid into the gaseous state will find some counterpart in the manner in which the analogous passage from the solid into the liquid state takes place. The character of these phenomena may be shown from direct observations of melting-point and pressure, as was done by the earlier observers. Full knowledge, however, can be obtained only by mapping out the isothermals throughout the region of fusion very similarly to the method pursued by Andrews himself for vaporisation. This has thus far been attempted for a single body only, naphthalene, within 130° and 2000 atmospheres. Six isotherms (63°, 83°, 90°, 100°, 117°, 130°) were traced within these intervals, along each of which, excepting the first, the body passed from the liquid to the solid state under the influence of pressure only. An exhibit of these data shows strikingly that in all cases the change of physical state takes place in accordance with a cyclic law; i.e. a larger pressure is necessary to change the body from the liquid to the solid state at a given temperature, than the pressure at which the body at the same temperature again spontaneously melts. Freezing almost always seems to take place at once; the corresponding fusion is apt to be prolonged, and in its gradual occurrence traces the contours of James Thomson's well-known doubly-inflected isothermals much more fully than does the allied case of vaporisation.

The appearance of the cyclic parts of these isothermals is suggestive, and may be described in terms of their dimensions in the direction of volume and of pressure respectively. The former dimensions indicate the probable fate of the volume increment. They show that as pressure and temperature increase, the volume increment tends more and more fully to vanish, and they thus imply a lower critical temperature at which the solid would change into the liquid continuously as far as volume is concerned. It does not follow that other properties of the body would here also vary continuously. For naphthalene this point would lie in a region of several thousand atmospheres, and several hundred degrees Centigrade—therefore in a region too remote to admit of actual approach.

Again, the breadth of the cycles, measured along the pressure

axis, decreases from the centre of the field both in the direction of increasing and decreasing pressures. The tenour of these results is an additional indication of the recurrence of a lower critical temperature at which cycles must necessarily vanish. The decrease of the breadth of the cycles in the direction of decreasing pressures suggests the possible occurrence of a point in the region of negative external pressure, so circumstanced that beyond it the substance would solidify at a lower pressure than that at which it fuses. This may be interpreted as follows: the normal type of fusion changes continuously into the ice-type of fusion through a transitional type characterised by the absence of volume lag.

An independent discussion, more searching in character, has quite recently been given by Tammann. Tammann points out that for the normal case of fusion and for increasing pressure, the two determinative factors of the Clapeyron equation—the volumes and latent heat of fusion—will not in general simultaneously become and remain zero. He argues that the volume constant will at the outset decrease with pressure passing through zero to negative values. Hence the curve representing the relation of melting-point to pressure must initially rise to a maximum when the melting-point pressure ratio is zero, and then decrease. Contemporaneously the latent heat of fusion, decreasing continually with pressure, eventually also reaches zero, but at a much later stage than the volume constant. At this stage, therefore, since melting-point and the volume constant now have definite values (the latter negative), the melting-point and pressure ratio is negatively infinite. Hence the curve expressing the relation of melting-point to pressure decreases with increasing pressure from the maximum specified as far as the pressure at which latent heat is zero, and there drops vertically downwards. Thus Tammann's melting-point pressure curve, with its initial and final ordinate in the direction of temperature, maps out a field of pressure and temperature, within which the body is solid. Outside of this region the body is liquid, and cannot by pressure alone be conceivably converted into the solid state. Any thermodynamic change involving a march through the boundary of this region is accompanied by the discontinuity of fusion, of viscosity, &c. A march through the final ordinate (for which latent heat is zero) is probably not accompanied by such discontinuity. For a given temperature there may be two fusion pressures. At a temperature sufficiently below the melting-point, the continued increase of pressure should therefore move the normally fusing body from the solid into the liquid state continuously. This is a somewhat anomalous result of close reasoning; but it must not be forgotten that in the depth of our ignorance of the actual occurrences above several thousand atmospheres, the term anomaly is a misnomer. Indeed, if we regard the melting-pressure curve beyond the stated maximum as characterising the ice-type of fusion (which Tammann does not do), our difficulties would in a measure be reconciled.

Tammann finally points out that the term lower critical temperature is not justified by the character of the phenomenon. Data for melting-point and pressure, due to Damien, seem directly to corroborate the occurrence of zero values in the ratio of melting-point and pressure increments, but Damien's tests are restricted to a pressure interval much too small to be trustworthy. Of the two bodies which have been tested throughout long-pressure intervals, naphthalene shows a linear melting-point and pressure ratio for 2000 atmospheres, while the carbon tetrachloride of Amagat, though initially concave upwards, soon also becomes linear. Clarence King has therefore, in geological considerations, so represented it. To conform with Tammann's inferences the interior of the earth would have to be a fluid.

One point of issue, however, in these cases is clear: at Andrews' critical temperature both the difference of specific volumes and the latent heat of fusion vanish simultaneously wherever observed. Under corresponding conditions of change from liquid to solid, the internal pressures are of tremendously greater value for both states, and the passage of the solid into the liquid molecule may involve an immense transfer of energy without any corresponding change of volume: for the density of the molecule itself eludes observation. The manner of this isothermal change from one state to the next is in all cases along the characteristic doubly inflected contour first pointed out by Thomson for vapours, and since elaborated by Van der Waals, Clausius and others. We may for brevity call this a *volume lag*, and measure it in terms of the pressure or the volume interval

subtended. The liquid can exist even above the critical temperature, which would mean that even here pressure must be reduced below the critical pressure in order to rupture the liquid molecule.

Pronounced as these phenomena are for the change from gas to liquid, they become much more remarkable, indeed often formidable, for the change from liquid to solid. In this case a volume lag subtending more than 100 atmospheres is the rule; in other words, it takes a much greater pressure to solidify a liquid at a given temperature than to liquefy the solid. Among all these cases there is a group of well-known bodies in which, while the solidification pressure is of marked intensity, the isothermal pressure of spontaneous fusion may even be below zero, or be in the region of negative pressure. Take the single example of thymol, among many: this body between zero Centigrade and its melting point at 53°, can be kept in either the solid or the liquid state at pleasure. Given at about 50° in the liquid state it would require more than 2000 atmospheres to solidify it. If solid, it must obviously remain so even if pressure be wholly removed. But thymol may be similarly treated, beginning with the under-cooled liquid state at 28°, i.e. 25° below its melting point. Even here at least one thousand atmospheres are needed to condense it (400 have been tried quite ineffectually). Once solid, it would require about 1000 atmospheres of negative external pressure again to melt it. In other words, it could not be melted again on the same isothermal.

If we but knew more about the physical constants involved in these transformations, we could predict the results along the lines of J. W. Gibbs's splendid theory of the equilibrium of heterogeneous mixtures; but with the dearth of our concrete knowledge of long range physical phenomena relating to liquids and solids, we must be content with humbler methods.

I have always regarded the significant behaviour, instanced for the case of thymol, as capable of a broad interpretation. Profs. J. J. Thomson and Fitzgerald in the British Isles, and Elihu Thomson in America, have recently sought for atomic dissociation in the electrolysed vacuum of a Crookes' tube. Speaking to the same point, I would venture to assert that we may reasonably look to the volume lag for a rational account of the genesis of atoms. We have already met with two orders of volume lag: the first at the emergence of gas into liquid being usually a few atmospheres in isothermal value; the second at the emergence of liquids into solid, a hundred or even one thousand times as large in isothermal value, and characterised by the fact that, whereas freezing pressures may be enormous, the corresponding isothermal melting pressure may even be markedly negative.

If then we further inquire as to what will happen if we indefinitely compress the solid along a suitable isothermal, I think it is logically presumable that, with the succeeding and profoundly accentuated volume lag, we shall reach the next atom in a scale of increasing atomic weights.

However enormous the condensation pressure for this purpose may be, it is supposable, in the light of the examples already given that, along an accessible isothermal, the disintegrating external pressure of the new atom may be permanently negative. Hence the new atom will persist within the pressure and temperature range available in the laboratory.

But the last stage is virtually identical with the first, or the inherent nature of these changes is periodic. The inference is therefore that, under suitable thermal conditions and continually increasing pressure, the evolution of atoms, of molecules, of changes of physical state, again of atoms and so on indefinitely, are successive stages of periodically recurring volume lag.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE Rev. A. M. Fairbairn, Principal of Mansfield College, Oxford, will distribute the prizes to the successful students of St. Thomas's Hospital on Saturday, October 2, at 3 p.m., in the Governors' Hall.

PROF. ROBERT G. AITKEN and Mr. W. H. Wright have been appointed assistant astronomers at the Lick Observatory.

A NEW centre of the London County Council Technical Education Classes will be opened next Monday evening, October 4, at the Charterhouse and Rogers' Memorial Institute, Goswell Road, E.C. The committee of the school announce that workmen's classes in workshop arithmetic, workshop chemistry and physics, workshop drawing and mechanics will be conducted.

THE revised regulations relating to the subjects of examination for degrees in science at the University of London were published a few days ago. The regulations come into force at the beginning of 1899. The subjects for matriculation are Latin, English, mathematics, general elementary science (a new subject), and any one of the following languages or sciences:—Greek; French; German; Sanskrit; Arabic; Elementary Mechanics; Elementary Chemistry; Elementary Sound, Heat, and Light; Elementary Magnetism and Electricity; Elementary Botany. The general elementary science refers to the physical and chemical properties of matter, and the subject will be treated, wherever possible, from an experimental point of view, numerical examples or problems being restricted to very simple calculations. In the intermediate examination in science, candidates will only be required to take up three of the following subjects, viz.: (1) Pure and mixed mathematics; (2) experimental physics; (3) inorganic chemistry; and (4) botany and zoology. It will thus be possible for students of physical science to obtain a pass or take honours without studying the biological subjects; and, on the other hand, biological students will not need to take up mathematics. For the final B.Sc. examination, eight subjects are given, and candidates will be examined in any three of them. The subjects are:—Pure mathematics, mixed mathematics, experimental physics, chemistry, botany, zoology, animal physiology, geology, and physical geography. All the syllabuses have been revised, and their general tendency is towards a fuller practical knowledge of the subjects than has hitherto been expected from candidates.

PERHAPS the most critical period in the career of a man of science is when he has completed his college course but has not established himself sufficiently to obtain a post of any value. For the benefit of promising students thus situated, the municipality of Lyons has, it is stated, decided to make some provision. According to the announcement, the municipality proposes to lend to young men on leaving the University the funds necessary "for their first needs," on their simple word of honour to repay the sum advanced as soon as their pecuniary position allows them to do so. The *British Medical Journal*, in referring to this action, says:—A similar humane principle has indeed long been acted upon by the Union des Anciens Étudiants de l'Université Libre de Brussels, which not only provides bursaries for deserving poor students, but in case of need procures employment for them after graduation, and in some cases a loan to start them in a profession. But this is the work of a private body, and the help that can be given is on a much smaller scale than the Lyons municipality proposes to give. The German Government, in certain cases, allows students to go through the University curriculum without payment of fees on their undertaking to discharge the liability when they are able to do so, and the old University of Paris was sometimes equally accommodating. It is often, however, even more difficult to find a market for academic and professional knowledge than to acquire that knowledge, and it is to such cases that the Lyons municipality proposes to lend the needed helping hand. The Fellowships of the older universities of this country have a distinct use for the same purpose, but they are for the few, and not always for those who most need them, nor perhaps for those who would make the best use of them. The Companies of the City of London seem not infrequently to find it difficult to dispose of their unearned increment in a really useful way. We venture to commend to them the example of the City of Lyons. We also congratulate the University of Lyons on its connection with a Corporation so enlightened and so anxious to further its interests.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, September 20.—M. A. Chatin in the chair.—On the hypocycloid with three inflections, by M. Paul Serret.—On oxycellulose, by M. Léo Vignon. This substance is prepared from cellulose by the action of hydrochloric acid and potassium chlorate, and its composition is expressed by the formula $C_{28}H_{38}O_{21}$. Its absorptive power for dyes is greater than that of cellulose. Oxycellulose behaves as an aldehyde towards Schiff's reagent.—On retamine, by MM. J. Battandier and Th. Malosse. The combination of this base with hydrobromic, sulphuric, and hydriodic acids have been prepared, the last-named being obtained in fine crystals, $C_{12}H_{28}N_2O_2 \cdot 2HI$.—The influence of colouring matters upon the fermentation of highly coloured red wines, by MM. P. Carles and G. Nivière.

The incomplete transformation of sugar into alcohol in highly coloured wines is not due to the acidity, but to the antiseptic action of the colouring matter itself.—On the function of *Pseudomonas vitis* (Debray) in two diseases of the vine, by M. E. Roze.

BOOKS, PAMPHLETS, and SERIALS RECEIVED.

Books.—Quantitative Chemical Analysis: Profs. Clowes and Coleman, 4th edition (Churchill).—City and Guilds of London Institute, Programme of Technological Examinations, Session 1897-98 (Whittaker).—Traité Élémentaire de Mécanique Chimique fondée sur la Thermodynamique: Prof. P. Duhem, Tome 2 (Paris, Hermann).—Glimpses into Plant Life: Mrs. Brightwen (Unwin).—Organic Chemistry for the Laboratory: Prof. W. A. Noyes (Easton, Pa., Chemical Publishing Company).—University College, Bristol, Calendar for the Session 1897-98 (Bristol, Arrowsmith).—Thermogeographical Studies: C. L. Madsen (Williams and Norgate).—International Congress on Technical Education. Report of the Proceedings of the Fourteenth Meeting, held in London June 1897 (Trowce).—An Introduction to Geology: Prof. W. B. Scott (Macmillan).—In Northern Spain: Dr. H. Gadow (Black).—Epping Forest: E. N. Buxton, 4th edition (Stanford).—Vorlesungen über Bakterien: Dr. A. Fischer (Jena, Fischer).—Among British Birds: O. A. J. Lee, Part 6 (Edinburgh, Douglas).—Diagrams illustrating Principles of Mining: F. T. Howard and F. W. Small (Chapman).—Elementary Practical Physiography (Section 1): J. Thornton (Longmans).—First Principles of Electricity and Magnetism: C. H. W. Biggs (Biggs).—University Geological Survey of Kansas, Vol. 2 (Topeka).—British Central Africa: Sir H. H. Johnston (Methuen).—Elementary Geometrical Statics: W. J. Dobbs (Macmillan).—The Story of Germ Life: H. W. Conn (Newnes).—The Mathematical Psychology of Grating and Boole: M. E. Boole (Sonnenschein).—Deductive Physics: F. J. Rogers (Ithaca, N.Y., Andrus).—Wild Neighbours: Outdoor Studies in the United States: E. Ingersoll (Macmillan).—Lectures on Physiology. 1st Series. On Animal Electricity: Dr. D. J. Waller (Longman).—Les Choses Naturelles dans Homère: Dr. A. Kums (Anvers, Buschmann).—University College of North Wales, Calendar, 1897-98 (Manchester, J. E. Cornish).

Pamphlets.—Glacial Observations in the Umanak District, Greenland: Prof. G. H. Barton (Boston).—Theory of the Motion of the Moon: Dr. E. W. Brown (Royal Astronomical Society).—A Descriptive Catalogue of Useful Fibre Plants of the World: C. R. Dodge (Washington).—South American Trade of Baltimore: Dr. F. R. Rutter (Baltimore).—Some New Orchids from Sikkim: G. King and R. Pantling, pp. 1 and 2 (Calcutta).—Materials for a Flora of the Malayan Peninsula: Dr. G. King, Nos. 8 and 9 (Calcutta).—Flax-growing: Major Fraser (Cable Company).—Les Forces de la Nature, &c.: T. L. Bienkowski (Léopol).—Kritik der Exakten Forschung, F. Ego (Leiden, Brill).—Reisen in den Mollukken, &c.: Prof. R. Martin, 1^{ste} Liefg. (Leiden, Brill).—Mineral Statistics of the United Kingdom for the Year 1896 (Eyre and Spottiswoode).

Serials.—Psychological Review, September (Macmillan).—Journal of the Franklin Institute, September (Philadelphia).—Archives of the Roentgen Ray, July (Rebman).—American Journal of Science, September (New Haven).—Botanische Jahrbücher, Vierundzwanzigster Band, 2 Heft (Leipzig).—Physical Review, May-July (Macmillan).—Himmel und Erde, September (Berlin).—An Account of the Crustacea of Norway: G. O. Sars, Vol. 2, Parts 7 and 8 (Bergen).—L'Anthropologie, July and August (Paris).—Botanische Jahrbücher, Dreiundzwanzigster Band, v. Heft (Leipzig).—Proceedings of the Physical Society of London, September (Taylor).—Economic Journal, September (Macmillan).—Timehri, June (Stanford).—Zoologist, September (West).—Beiträge zur Psychologie und Philosophie, i. Band, 2 Heft (Leipzig).—Annalen der K.K. Universitäts-Sternwarte in Wien, x., xi. and xii. Band (Wien).—American Naturalist, September (Philadelphia).—Longman's Magazine, October (Longmans).—Sunday Magazine, October (Isbister).—Good Words, October (Isbister).—Annales de l'Observatoire Magnétique et Météorologique de l'Université Impériale à Odessa, 1896 (Odessa).—Memoirs and Proceedings of the Manchester Literary and Philosophical Society, Vol. 41, Part 4 (Manchester).—East Asia, No. 2 (Longton, Hughes).

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